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MEETINGS

of the

American Institute of Electrical Engineers

(See Announcements This Issue)

SUMMER CONVENTION, Detroit, Mich., June 20-24

Lake Trip - - June 25

PACIFIC COAST CONVENTION, Del Monte, Calif., September 13-16

REGIONAL MEETING

Pittsfield, Mass., *North Eastern District No. 1,* May 25-28

MEETINGS OF OTHER SOCIETIES

National Electric Light Association
Middle West Division, Topeka, Kans., May 18-20
North Central Division, Minneapolis, Minn.

The American Society of Mechanical Engineers, White Sulphur Springs, W. Va., May 23-26

Canadian Electrical Association, Niagara Falls, Ont., Canada, May 25-27

National Electric Light Association, Atlantic City, N. J., June 6-10

American Association of Engineers, Tulsa, Okla., June 6-8

Pacific Coast Electrical Association, Santa Cruz, Calif., June 14-18

Northwest Electric Light and Power Association, Salt Lake City, June 21-24

American Society of Civil Engineers, Denver, Colo., July 13-16

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Vol. XLVI — MAY, 1927 — Number 5

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

Continued on next page

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address be sure to mention the old one, indicating also any change in business connections.

(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

Institute and Related Activities—*Continued.*

Current Electrical Articles Published by Other Societies

Bureau of Mines Technical Paper 375, (1926)

Effects of the Corona Discharge on Petroleum, by J. J. Jakosky

The Institute of Radio Engineers Proceedings, April 1927

Piezo-Electric Crystals at Radio Frequencies, by A. Meissner

Quantitative Measurements on Reception in Radio, by G. Anders

The Frequency Checking Station at Mare Island, by G. T. Royden

Transactions of the Illuminating Engineering Society, April 1927

Under Water Illumination, by S. G. Hibben and W. A. McKay

Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLVI MAY, 1927 Number 5

Voltage Standardization

A report on voltage standardization, by B. G. Jamieson, was presented at the Bethlehem Regional Meeting, based upon the symposium on this subject given at the 1927 Winter Convention of the Institute.

The following excerpts from Mr. Jamieson's report gives a very clear conception of the status of this problem which involves many conflicting views.

"This subject, recognized as preeminently important for a number of years, came up before the Electrical Apparatus Committee of the N. E. L. A. in 1921-1922 in one of its many aspects, and in 1922 a complete scheme of transformer voltage standards was duly compiled and approved.

"In 1924 the manufacturers stated that less than 50 per cent of power transformers were being ordered in accordance with that standard, and an investigation by the Transformer Committee of the N. E. L. A. revealed that not only was further revision of transformer standards needed but that any such revision must take into account the whole electricity supply system from the generator to the consuming device, and therefore system surveys were begun.

"In 1926 the International Electrotechnical Commission held a meeting in New York, at which time standard system voltage was a major topic in the program of deliberations, and it became painfully evident that the United States was unable to present anything like a nationally indorsed schedule of electrical system voltages.

"The forced recognition of this dilemma brought about committee activity, which crystallized into a symposium on the subject presented under the auspices of the A. I. E. E. at its Winter Convention in New York City on February 9, 1927.

"At this meeting papers were presented representing the views of prominent consulting, operating and manufacturing engineers and one foreign engineer well posted on the status of this matter in Europe.

"These papers brought out forcibly and comprehensively the fixed capital aspects of this matter, as well as the regional influence, manufacturing economics, and other engineering fundamentals.

"They also expressed independent sentiment as well as criticism of the manufacturers' proposed treatment of this subject which had been published in the preceding September *Bulletin* of the N. E. L. A and served to focus the views of the several engineers in their attack on the problem.

"An analysis of these papers, of the discussions which followed, of the press comments which subsequently appeared, and of the fundamentals of the problem, furnished the material for further consideration of th topic by the special N. E. L. A. Committee."

The studies of this committee have just resulted in recommendations for preferred system voltages which were presented in tabular form at the Bethlehem meeting. This tabulation of Preferred Voltage Ratings for A-C. Systems and Equipment is of course tentative and is to be considered at this time as only a preliminary report of progress for the purpose of putting this important matter as promptly as possible before those who took part in the Institute symposium.

The report states that carefully prepared statistics by regional operating organizations on the West Coast and in the South have been of greatest assistance, as has been the help of manufacturing interests as well as that engineering talent which represents the Metropolitan districts and those interests widely dispersed over the country. Agreement among these engineers on the principles which underlie any possible settlement of this problem either wholly or in part must be accounted of the highest order of value in this day of imminent although, from an engineering viewpoint, somewhat indiscriminate system interconnection.

It is evident that the committee has used painstaking effort to include all important considerations in its report and has kept in mind the practical requirements while seeking an ideal solution.

A. I. E. E. Members Going Abroad

Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitles members of the Institute while abroad to membership privileges in those societies for a period of three months, and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate for the use of Institute members desiring to avail themselves of these exchange privileges, which serves as credentials from the Institute to the foreign societies, may be obtained upon application to Institute headquarters, New York.

The societies with which these reciprocal arrangements have been established and are still in effect are:

Institution of Electrical Engineers (Great Britain), Societe Francaise des Electriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Denki Gakkwai (Japan), Norsk Elektroteknisk Forening (Norway), and Elektrotechnicky Svaz Ceskoslovensky (Czechoslovakia).

Some Leaders of the A. I. E. E.

Charles Francis Brush, Charter Member of the Institute, scientist and Edison medalist for 1913, was born at Euclid, Ohio, March 17, 1849, both of his parents coming from old American families. His grammar and high school education was obtained in the public schools of Cleveland from which he was graduated at an early age. While still at school, he became intently interested in electrical apparatus and, in true boy fashion, experimented with his own construction of static machines, induction coils and small motors. His graduating essay, in fact, was on the dynamo and arc light, based upon the Wilde experiments in London. In 1869 he was graduated in mining engineering, from the University of Michigan, returning for a postgraduate course which won for him his M. S. degree, followed by a Ph. D. from the Western Reserve University. This latter university also conferred upon him an honorary degree of LL. D., as did also the Kenyon College in 1903.

It was in 1860 that the Italian, Paccinotti, made a great discovery in electricity, but it was destined to remain buried in the archives of Italian libraries until a young Belgian by the name of Gramme reinvented the dynamo electric machine. Doctor Brush, then a young man just out of college, was one of the first to realize the value of this "neucleus" and to undertake further the history of its evolution and application with variation and improvement. By 1876 he had designed a dynamo—constructed under his own supervision—a pioneer machine to be exhibited at the Paris Exposition in the United States Historical Exhibit. In 1877 he introduced the compound field winding for constant potentials now so generally applied to electric lighting; its first use was in connection with plating machines. At the Charitable Mechanics' Fair in Boston, (1878), an exhibit of greatest historic and scientific interest, was displayed the earliest form of what afterward became the world-famous Brush arc light machine. His, too, was the great invention of the differential arc lamp, the construction and operation of which included the principle making it possible to operate lamps in series instead of in parallel. He also developed another apparatus of great significance,—the automatic cut-out, permitting each lamp to cut itself out of circuit should trouble arise or the carbon burn out. This was looked upon as one of the greatest inventions of the era—conceded by even Doctor Brush's contemporaries in the same field of development. From that time on it was a rapidly growing industry. Copper plating of carbon electrodes was also introduced by Doctor Brush and yielded large royalties. In 1881 the Brush Electric Company was incorporated and capitalized at $3,000,000. Approximately ten years later when the General Electric Company was formed, it absorbed this company and the works were removed from Cleveland to Schenectady, but in the meantime, through the formation of other corporations, the Brush apparatus and system were being introduced. The storage battery problem was also receiving considerable attention from Doctor Brush, and as a result of his effort, great improvement was accomplished in the manufacture of lead plates. By Doctor Brush, also, was devised the ingenious system of charging storage batteries from an arc light system and the subsequent subdivision of light, demonstrating that it was possible to run incandescent lights on an arc light circuit. In 1881 at the International Electrical Exposition in Paris there was exhibited by the English Brush Company as one of the most interesting features, a certain Brush apparatus. In this year, also, Doctor Brush was decorated by the French Government as Chevalier of the Legion of Honor; in 1889, the American Academy of Arts and Sciences awarded to him the Rumford medal, bestowed by both the Royal Society and the American Academy of Arts and Science, "for the most important discovery or useful improvement on heat and light." Doctor Brush is a corporator of the Case School of Applied Science, trustee of the Western Reserve University, Fellow of the American Academy of Arts and Sciences; member of the Physical Society, the American Philosophical Society; Fellow of the American Association for the Advancement of Science; Life Member of the British Association, Ohio State Board of Commerce, Cleveland Chamber of Commerce (of which he was also president 1909-10); The American Society of Mechanical Engineers; member of the Archeological Institute of America, the American History Association, the National Electric Light Association, the Franklin Institute, the American Chemical Society, the Royal Society of Arts; Fellow of the American Geographic Society and the N. British Academy of Arts.

The strong, steady growth of power consumption throughout the United States started out in January of this year at about the same rate of increase shown by both 1925 and 1926. During January the country used 6,714,000,000 kilowatt-hours of electric energy to light its homes and streets, to operate its industries and to do the thousand other things that electricity does. This is 10 per cent ahead of January, 1926 and that month was 10 per cent in advance of January, 1925.

This year water power started out a little stronger than it did in 1926. In January, 35 per cent of the country's electric energy was generated by the force of falling water and the balance by fuels.

Constant-Current Regulating Transformer Characteristics

Special Tests Show Radical Differences From Conventional Assumptions

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and

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Synopsis.—*It has generally been assumed that the total losses of a constant-current regulating transformer remain practically constant for all loads. Performance and test calculations have accordingly heretofore been made according to well known conventional methods from the segregated losses determined from test or design data, assuming total losses constant. Extensive tests described in the paper show, however, that these losses are not necessarily even approximately constant, but for some transformers vary greatly with the load, the total losses at light loads greatly exceeding those at full load.*

The tests further show that the increased losses produce increased temperature rises at light loads, which may be sufficiently excessive to endanger the apparatus, although the same transformer may be able to carry full load with normal temperature rise.

The increased total losses and temperature rises at light loads are shown to be due largely to the increase of stray load losses with decrease of load, caused mainly by the leakage flux inducing excessive circulating currents in the laminations and structural parts of the transformer, such as the cage. Exploring coils and iron filings were used to investigate the amount and direction of the leakage flux.

Performance specifications should be based on the actual total losses for all loads and not on the conventional assumption of constant total losses, as has been done in the past.

It is pointed out that the characteristics described depend somewhat on the design, other features besides liberality in the use of materials being of importance. Consequently, measures should be taken by designers to correct these undesirable characteristics as much as possible. Users not only desire the most highly efficient apparatus consistent with cost, but must have apparatus of the highest reliability under all possible conditions, which cannot be expected of constant-current transformers endangered by excessive temperatures at light loads. The characteristics discussed are, therefore, not only of theoretical interest, but also of considerable practical interest to both designer and user.

THE general theoretical principles usually accepted and applied to performance calculations and tests of moving-coil constant-current transformers have been based on certain conventional assumptions which have heretofore been generally accepted without question. It has generally been assumed that the total losses of a constant-current transformer remain practically constant for all loads, that is, for all coil positions.

The reasons for this are based on simple fundamental considerations. Inasmuch as the applied voltage remains constant for all loads, and the resultant magnetic flux nearly so, it seems reasonable to assume that the core loss should also remain practically constant. Furthermore, inasmuch as the current in both primary and secondary remain practically constant, changes of load being changes in secondary voltage effected by variation of leakage reactance with position of the coil producing power factor changes only in current, the copper losses should also be practically constant. It was also assumed that the stray load losses did not vary greatly with the load.

The more exact reasoning leading to the assumption of constant losses is that the iron loss and copper loss both vary somewhat, but in such a way as to keep the total losses practically constant. Under the condition of full load, the magnetic leakage is a minimum, the entire magnetic circuit is excited to nearly its maximum density, and the core loss a maximum. At reduced loads, more of the flux passes across the open space between the legs, thus reducing the flux in parts of the core, consequently, decreasing the core loss. So the core loss would be greatest at heavy loads, and slightly lower at light loads. Considering the copper loss, the $I^2 R$ component remains constant, but the eddy current component is less at full load and slightly greater at light loads. On this basis the total losses would be practically constant for all loads.

Performance and test calculations were therefore formerly made according to well known conventional methods from segregated losses determined from test or design data. The segregated losses were determined under conditions corresponding to full load, and the values thus determined used as the losses for other loads as well as for full load.

Actual Characteristics Differ Greatly from Theoretical

Tests made by the writers, however, showed that the total losses were not necessarily even approximately constant, but for some transformers varied greatly with the coil position and consequently the load. In most cases the losses at light loads were found to greatly exceed those at full load. This condition is contrary to the usual performance of most electrical machinery. This increase of losses with decrease of load is plainly shown in Fig. 1.

This deviation of actual performance from that conventionally assumed is not only of theoretical interest but of great practical significance to both manufacturer and operator. It means that the losses at light

1. Both of the Consolidated Gas, Electric Light and Power Co., Baltimore, Md.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

loads are much greater than supposed, consequently the cost of supplying these losses appreciably increases the cost of current supplied to series lamps. It makes it desirable for users to operate constant-current transformers close to full load but this is not always practical under actual conditions.

Standard tests and manufacturers' guarantees have been based on the assumption of constant losses. This has given misleading fictitious values for the losses and efficiences at the lower loads. Referring to Fig. 1, at

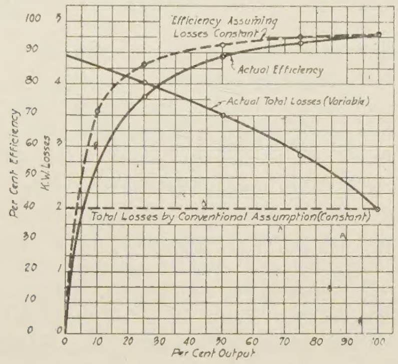

Fig. 1—Actual and Conventionally Assumed Variation of Total Losses in a Constant-Current Transformer with Load

full load the losses are two kw. and the efficiency 96 per cent according to both methods. At one-quarter load, the actual loss is four kw., that is, twice that assumed by the conventional method, and the actual efficiency is 76 per cent as against 86 per cent based on the conventional method.

Temperature Characteristics Unusual

Another consideration which is exceedingly important is the effect on the temperature rise of the transformer. The increased losses will produce increased temperatures at light loads, which may not only exceed the temperature guarantees, but may endanger the apparatus. Conventional temperature tests on constant current transformers were formerly made under conditions corresponding to full load. Tests made by us, however, showed that temperature rises were higher at light loads than at full load due to the greater losses at light load. Transformers which have satisfactorily passed the standard temperature tests may develop excessive temperatures at light loads. This is shown in Fig. 2. This condition is contrary to our usual experience with electrical apparatus, which is that temperature rises are ordinarily greater at heavy loads than light loads.

Due to the arrangement of circuits, changing load conditions and necessary spare capacity allowances, it is not always practical to run all constant-current transformers at full load, but many of these must be run at light loads. Consequently, some of these may overheat and ultimately break down, even though they may be able to operate satisfactorily at full load without reaching excessive temperatures. The transformer of Fig. 2 shows a temperature rise in the iron of 55 deg. cent. at full load, which does not exeeed the normal allowable limit. At one-half load the rise is 86.5 deg. cent. and at one-quarter load the rise is 93.5 deg. cent. which greatly exceeds the allowable limit.

Factors Affecting These Characteristics

This variation of losses with load is more marked in some transformers than in others, depending somewhat on the design. As some of the older transformers were designed along very liberal lines, this variation was so small comparatively, as to justify the assumption of constant losses. The variation is most marked however, in modern designs in which materials are worked to the limit, a condition typical of modern design in general, brought on by economic necessity and the stress of competition.

Liberality in the use of materials is not the only factor affecting the performance as described, but there are other factors which play an important part. We made a number of tests trying to analyze some of these, and to find some of the underlying causes and provide a theory to account for some of the particular characteristics described.

Stray Load Losses

The results of our tests indicate that the stray load losses are mainly responsible for the effects described. The leakage fluxes vary greatly in amount with the load, causing the stray load losses to increase greatly with decrease of load. In some cases these may equal or exceed the total of the other losses. In most elec-

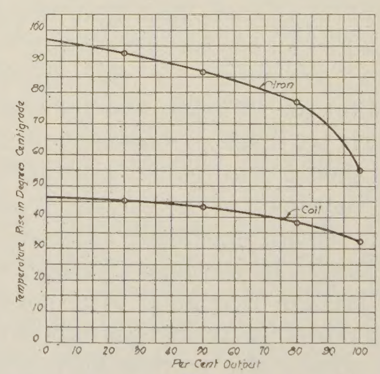

Fig. 2—Effect of Load on Temperature Rise of Constant-Current Transformers

trical apparatus the stray load losses, which are small at light loads and greatest at heavy loads, are usually considerably less than the other losses.

The direction of the leakage flux has a very important bearing. As shown in detail later on, the leakage flux leaves the laminations not only by the edges, but a large proportion of it leaves from the sides perpendicular to the plane of the laminations, producing a heavy eddy current loss in these, with consequent heating. Furthermore, this is the part of the leakage flux which is most likely to encounter in its path metallic struc-

tural parts of the transformer, thus producing eddy currents in these parts. Fluxes leaving in the direction of the edges will produce comparatively small losses of this nature.

The total effect will therefore depend greatly upon the distribution of leakage flux resulting from the design. As the leakage flux increases with decrease of load, a transformer in which much of the leakage flux passes from the sides of the laminations will show greatly increased losses of this nature at light loads.

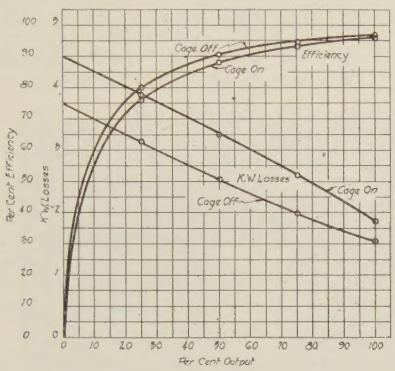

Fig. 3—Effect of Cage on Operation of Constant-Current Transformer

A marked example of losses in structural parts of a constant current transformer was the stray load loss in the protective cage, which was greatest at light loads, tests showing the large value of 3/4 kw. When the cage was removed, this cage loss was eliminated. Fig. 3 shows how the cage affected the total losses and the efficiency for various loads.

This marked variation of large stray load losses with load will therefore largely account for the great variation of total losses with load characteristic of some constant-current transformers. When the stray load losses are comparatively small the conventional assumption of constant losses is reasonably correct. However, when these are comparatively large the total losses will increase noticeably with decrease of load.

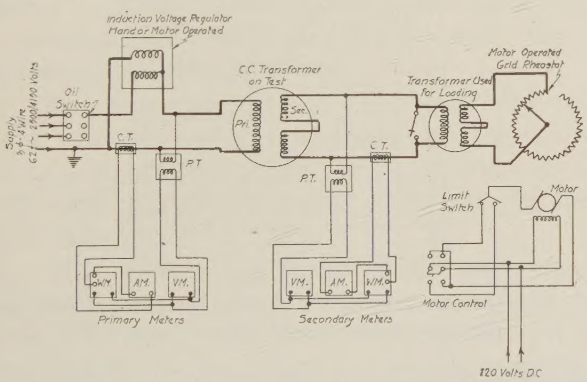

Fig. 4—Wiring Diagram of Constant-Current Transformer Test showing Meter Connections and Method of Loading

Efficiency and Loss Tests

Efficiencies and losses were determined by input—output method, tests being made on different makes and sizes of transformers at various loads and voltages. The scheme of connections used during the tests is shown in Fig. 4. This gave good control of voltage and load. Due to the use of transformers in the secondary circuit, the power factor in this circuit was slightly less than unity. The main effect of this was to materially reduce the maximum capacity of the transformer.

However, as long as the secondary power factor was kept nearly constant throughout a particular test from no load to full load, the characteristics of the transformer were not altered.

The transformers tested were rated at 6.6 secondary amperes and at either 2300 or 2540 volts primary. Most of the tests were made on 60-cycle transformers at an actual frequency of 62.5 cycles, this being the frequency of our nominal 60-cycle system. A few tests were also made on 25-cycle transformers.

Readings were taken of voltage, current and kw. on both primary and secondary side, meters being read as closely as possible. Although absolute accuracy is not claimed for the instruments used and methods of measurement they were of sufficient practical accuracy for the purpose. This was shown by the general consistency of the loss measurements, and by the fact that the temperature runs gave results in line with the loss measurements. For example, as wattmeters are more subject to error at low power factors than at high power factors, the wattmeters on the primary side would tend to show higher losses at light loads than full load, due to the much lower power factors. However, not only was the actual possible error due to this cause far from being large enough to account for the great increase of losses shown by our results, but the greatly increased temperature rises actually measured proved that these represented actual additional losses rather than errors of measurement.

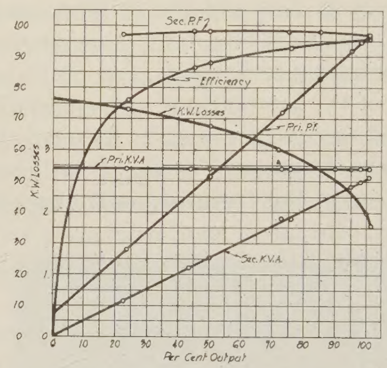

Fig. 5—Typical Performance Curves of Constant-Current Transformer

Efficiencies, power factors, and losses were calculated from the readings. Fig. 5 shows typical performance curves determined by actual test.

Temperature Tests

Temperature tests were also made on different makes and sizes of transformers under various conditions of load and voltage, to determine the effect of the load carried upon the temperature rise of various parts. These temperature runs were made with the same scheme of connections as for the efficiency tests shown in Fig. 4, that is, with test conditions the same as actual load conditions.

Temperatures were measured by means of thermometers and thermocouples placed in numerous locations on the iron core and the primary and secondary coils. The maximum iron temperatures were found to be on the center leg of the iron core, on the side parallel to the sides of the laminations, somewhere between the primary and secondary coils. Typical temperature rise curves are shown on Fig. 6. It will be noted that the floating coil of this transformer shows a temperature rise of 65 deg. cent. at ¼ load, whereas it had previously shown a temperature rise of only 55 deg. cent. at full load.

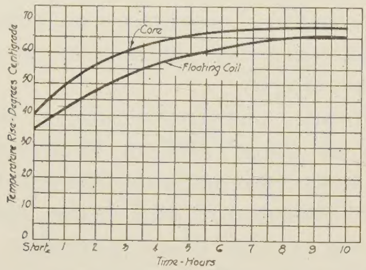

Fig. 6—Maximum Temperature Rise in Constant-Current Transformer Operating at One-Quarter Load

Exploring Coils used to determine the Amount and Characteristics of the Leakage Flux

Exploring coils consisting of several turns of small wire were wound around each of the three legs of the transformer. These coils were so arranged that they could be moved up and down the core. The voltage induced in these windings is a measure of the amount of flux at that particular point in the iron core. Moving the exploring core further up and further down the coil showed a change in voltage in the coil which represents an increase or decrease in magnetic flux in that core. The results obtained with the use of these exploring coils are shown in Fig. 7. It can be noted from the curves on Fig. 7 that the rate of change of flux throughout the entire distance between the primary and secondary coils is practically uniform. This means that the leakage flux leaving a narrow section near one coil, say on short circuit, is practically the same as the flux leaving a similar narrow section near the other coil. It was found from these tests that the flux per unit section between the primary and secondary coils was the same regardless of the position of the moving coil, provided, of course, that the primary voltage and secondary current and power factor were held constant.

To determine the amount of leakage flux leaving the core perpendicular to the core laminations, exploring coils were wound on the face of the sides on both the center leg and the two outside legs of the iron core. The voltage obtained on these cores is an indication of the amount of flux entering or leaving that portion of the circuit. When reduced to a unit area basis, it was found that the leakage flux leaving the center core perpendicular to the laminations was, in most cases, 45 per cent or more of the total leakage flux. The total leakage flux entering the two outside legs perpendicular to the laminations was only 25 per cent of the total transformer leakage flux.

The fact that so much flux leaves the center core perpendicular to the laminations accounts for the high temperatures found on that portion of the iron core and for at least some of the increased losses with decreased load, this being due to the fact that much more leakage flux occurs at no load than at full load.

Using a small exploring coil about one in. in diameter, the passage of the flux from the center leg to the outside leg was traced. With this coil it was found that a considerable portion of the leakage flux passes through the region normally occupied by the expanded metal protecting cage around the outside of the transformer. The amount of this leakage flux is sufficient to cause considerable induced currents in the screen. Careful

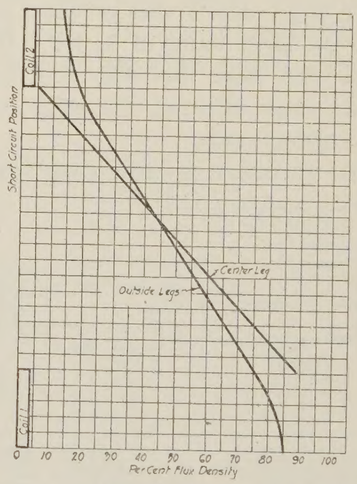

Fig. 7—Flux Densities in Cores of Constant-Current Transformer when Short-Circuited

measurements made on different transformers showed that in maximum conditions, the loss in the cage may amount to as much as 20 per cent of the total losses measured. This maximum loss occurs at short circuit when the leakage flux is greatest. As the load increases and the coils come closer together the loss in the screen is decreased slightly.

Flux Distribution Shown by Iron Filings

The flux distribution was also studied by means of iron filings spread on paper placed around the core. Photographs of these were taken, Figs. 8 and 9 showing reproductions. These show the flux distribution in the

air-gap between the center leg and outer legs of the core for two different transformers under load. The iron filings show how the flux leaves the center core and travels to the outside legs. Both of these show that not only does the flux pass from the edges of the center core to the outside legs, but a large amount of flux leaves the center core practically perpendicular to the laminations. On the other hand, on the outside legs, the greater proportion of this same part of the leakage flux passes around and enters at the extreme outside edges. That is, the leakage flux path to the outside legs is mainly to the inner and outer edges, the proportion of flux entering perpendicular to the laminations being considerably less than that in the center leg of the core.

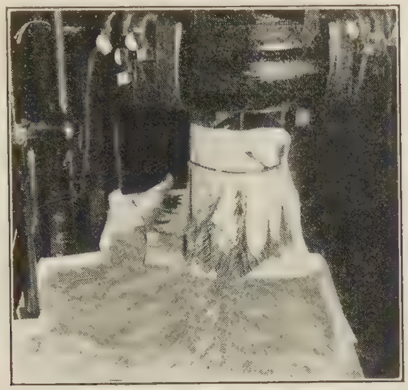

Fig. 8—Direction of Leakage Flux in Constant-Current Transformer under Load Illustrated by Means of Iron Filings

Conclusions

1. The results prove conclusively that the total losses of a constant-current moving-coil transformer are not constant, but may vary greatly with the load, increasing with decrease of load.

2. The increased losses at light loads may be sufficient to cause excessive and dangerous temperature rises in a transformer at light loads, although the same transformer may be able to carry full load with normal temperature rise.

3. This increase of total losses and increased temperature rises at light loads are due largely to the increase of stray load losses with decrease of load, caused mainly by the leakage flux passing from the core perpendicular to the sides of the laminations. These induce excessive circulating currents not only in the laminations themselves but in structural parts of the transformer, such as the cage.

4. Performance specifications, in order to be correct, should be based on the actual total losses for all loads. The conventional methods hitherto used based on constant total losses give highly misleading results. More attention should be given to the framing of specifications which should include such details as are necessary to show the true characteristics of the transformer, and to enable its fitness for particular operating conditions to be determined.

Some constant-current transformers are equipped with a light-load tap, which accomplishes reduction of secondary voltage by a change of ratio. This reduces the leakage flux and resulting stray load losses for a given load. While such a tap can be used to advantage under some conditions, tap changing is not always practical, such as under changing load conditions due to shifting of circuits. Specifications should not only cover the performance for the reduced capacity tap as well as for full winding, but should also clearly indicate on which each part is based. Some specifications do not indicate whether the performance at light loads is based on the full winding or on the reduced capacity tap.

5. Measures should be taken by designers to correct as far as possible the undesirable characteristics described. Aside from a more liberal use of materials, it should be possible to accomplish much by other design features A few possibilities are here suggested. The loss in the metallic cage can be eliminated by replacing this by a non-metallic guard. Losses in the laminations can be reduced by making these narrower. The use of a cruciform core, if practical, would also reduce the losses in the laminations by providing edges for the flux to leave in all directions thereby reducing to a minimum the flux leaving perpendicular to the sides of the laminations.

In this connection it is desired to point out that the extra cost of a properly designed constant-current transformer may be offset by the savings which will result from reduced losses. It may also be possible to get the desired characteristics without materially increasing the cost of the transformer.

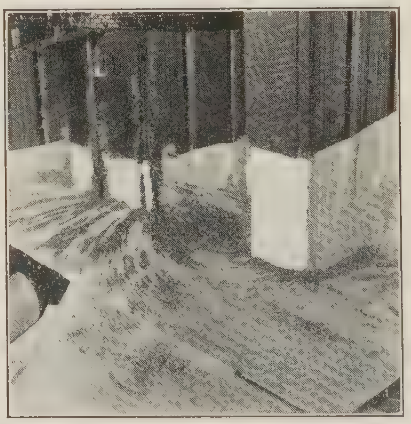

Fig. 9—Second Illustration of Leakage Flux by Means of Iron Filings Showing How This Leaves the Sides as well as the Inside and Outside Edges of the Laminations

Aside from the savings in losses, continuity of service, which is of special importance in street lighting service, requires reliability in operation of all equipment supplying this service. Such service is endangered by using transformers which may break down due to heating on light loads.

Current Analysis in Circuits Containing a Resistance Modulator

BY L. S. GRANDY[1]
Associate, A. I. E. E.

Synopsis.—*The function of a resistance modulator is to produce in an electric circuit a current which is a copy of an exciting impulse such as speech or light waves. The principal example is the carbon granule telephone transmitter.*

It is desirable that the electric current be an exact copy of the exciting impulse. There is inherent in such a device however, a distorting effect, for the current copy is produced by reason of Ohm's law and thus is an inverse function of the modulated resistance and not a true copy of it. The amount of distortion arising from this effect depends upon the electrical constants of the modulator and its associated circuit.

The study quantitatively analyzes this distorting effect by two methods in a circuit containing a modulator, a battery and a resistance for single frequency modulation and by one of the methods for double frequency modulation. An analysis is also developed for a special test circuit.

The study shows that the relation between modulators and circuits is a design problem.

Introduction

In the sense used in this study a modulator is a device used to transform electrical energy supplied to it into a time copy of a desired mechanical impulse or so to modulate an electrical current that the result will be an electrical copy of an exciting wave. The exciting impulse may be any function of time. If the current to be modulated is supplied by a constant difference of potential it may be modulated by introducing into the circuit either a resistance or an electromotive force varying in accordance with the exciting impulse. The result will be a modulated current by reason of Ohm's law. The present subject is limited to modulation by the resistance method.

Two applications of the resistance modulator are the carbon-granule telephone transmitter and the selenium light-sensitive cell. Either of these pieces of apparatus forms a unit in a system which fails to transmit perfectly the exciting wave. In the case of the telephone, the characteristics of the speech input are not faithfully reproduced in the sound output at the receiver. The difference in characteristics or quality is termed distortion.

In order to perform a useful function a resistance modulator must be provided with a transmitting system that will cause the exciting wave to act on the resistance unit, and this system always causes distortion. Again using the carbon transmitter to illustrate; distortion of the voice wave occurs in the air transmission leading up to the button diaphragm because of mechanical characteristics of an air column, in the diaphragm because of its own mechanical qualities combined with clamping difficulties and in the carbon because of its mechanical behavior and because carbon does not have a linear pressure-resistance relation. However, these causes of distortion are all subject to modifications which will diminish such distortion.

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Note: Since this paper was written, the study has been extended to the series circuit containing resistance and inductance.

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For the purpose of the study a perfect resistance modulator is assumed. The resistance element gives a change of resistance which is an exact copy of the exciting wave. Thus the assumed perfect modulator represents the limit in quality which improved materials and design may produce in such a device. But, a resistance modulator gives a current wave in the output circuit which in form is an inverse function of the exciting wave and not a true copy of it. The result is distortion, such distortion being inherent in the nature of the device. In order to analyze the effect quantitatively, an exciting wave following the sine law is assumed. By assumption it produces a corresponding wave of resistance modulation. Then the resistance of the modulator will be a constant quantity plus the modulating resistance and may be written:

$$R_0 + r \cos \omega t.$$

The distortion effect is graphically illustrated in Fig. 1.

The amount of distortion occurring in a transmitting circuit due to modulation is determined by both the modulator and circuit electrical constants. The study contemplates a critical analysis of the modulated current from the quality standpoint. The usual method of analysis by harmonic components has been employed.

Simple Series Resistance Circuit

(First Development—Single Frequency)

Considering the most simple possible circuit; a battery, a resistance and a modulator in series.

Equation,

$$i = E/(R_x + R_0 + r \cos \theta)$$

Let

$$R_x + R_0 = R \text{ and } r/R = K$$

By simple division:

$$i = E/R \{ 1 - K \cos \theta + K^2 \cos^2 \theta - K^3 \cos^3 \theta + K^4 \cos^4 \theta + \ldots \}$$

The series converges—Proof

$$U_{n+1} < U_n \text{ and } L_{n \to \infty} U_n = 0$$

$$U_{n+1} = (r/R)^{n+1};\ U_n = (r/R)^n;\ (r/R)^{n+1} < (r/R)_n \text{ if } r < R$$

Also

$$L_{n \to \infty} (r/R)^n = 0 \quad \text{if } r < R$$

which is true always since the modulating resistance must be less than the total resistance.

Expanding: Whole expansion to be multiplied by E/R

Constant: $1 + K^2/2 + 3K^4/8 + 5K^6/16 + 35K^8/128 + 63K^{10}/256 + \ldots$

Fundamental: $-\cos\theta\,(K + 3K^3/4 + 5K^5/8 + 35K^7/64 + 63K^9/128 + \ldots)$

2nd Harmonic: $\cos 2\theta\,(K^2/2 + K^4/2 + 15K^6/32 + 7K^8/16 + 105K^{10}/256 + \ldots)$

3rd Harmonic: $-\cos 3\theta\,(K^3/4 + 5K^5/16 + 21K^7/64 + 21K^9/64 + \ldots)$

4th Harmonic: $\cos 4\theta\,(K^4/8 + 3K^6/16 + 7K^8/32 + 15K^{10}/64 + \ldots)$

5th Harmonic: $-\cos 5\theta\,(K^5/16 + 7K^7/64 + 9K^9/64 + \ldots)$

6th Harmonic: $\cos 6\theta\,(K^6/32 + K^8/16 + 45K^{10}/512 + \ldots)$

7th Harmonic: $-\cos 7\theta\,(K^7/64 + 9K^9/256 + \ldots)$

8th Harmonic: $\cos 8\theta\,(K^8/128 + 5K^{10}/256 + \ldots)$

9th Harmonic: $-\cos 9\theta\,(K^9/256 + \ldots)$

10th Harmonic: $\cos 10\theta\,(K^{10}/512 + \ldots)$

Each harmonic becomes an infinite series; hence an approximation. The expansion of a power of the cosine results in a single term for every even or for every odd harmonic starting with the same numbered harmonic as the power developed and going on down to the fundamental if an odd power or to the constant term if an even power. Thus in the expansion given the series become more approximate by twos.

From this solution a very clear mental picture of the process of modulation may be gained. The fundamental or first harmonic is the result of the direct current flowing across the varying resistance of the modulator, the second harmonic and the second constant term result from secondary modulation, that is, the fundamental flowing through the modulating resistance. Thus by reason of the eighth harmonic there arises the first term of the ninth series, the second term of the seventh, the third term of the fifth, the fourth term of the third and the fifth term of the first series.

Simple Series Resistance Circuit

(First Development—Double Frequency)

Equation

$$i = E/(R_x + R_0 + r_1 \cos\alpha + r_2\cos\theta)$$
$$= E/(R + r_1\cos\alpha + r_2\cos\theta)$$
$$= E/R\,[1/1 + K_1\cos\alpha + K_2\cos\theta]$$

Where

$$\alpha = 2\pi f_1 t \text{ and } \theta = 2\pi f_2 t$$

By division:

$$i = E/R\,[1 - (K_1\cos\alpha + K_2\cos\theta) + (K_1\cos\alpha + K_2\cos\theta)^2 - (K_1\cos\alpha + K_2\cos\theta)^3 + (K_1\cos\alpha + K_2\cos\theta)^4 + \ldots]$$

Writing in harmonic components: (Fourth order modulation)

The whole expansion must be multiplied by E/R.

$$1 + K_1^2/2 + K_2^2/2 + 3K_1^4/8 + 3K_2^4/8 + 3K_1^2K_2^2/2$$
$$- [K_1 + 3K_1^3/4 + 3K_1K_2^2/2]\cos\alpha$$
$$- [K_2 + 3K_2^3/4 + 3K_1^2K_2/2]\cos\theta$$
$$+ [K_1^2/2 + K_1^4/2 + 3K_1^2K_2^2/2]\cos 2\alpha$$
$$+ [K_2^2/2 + K_2^4/2 + 3K_1^2K_2^2/2]\cos 2\theta$$
$$- [K_1^3/4]\cos 3\alpha - [K_2^3/4]\cos 3\theta + [K_1^4/8]\cos 4\alpha$$
$$+ [K_2^4/8]\cos 4\theta$$
$$+ [K_1K_2 + 3K_1^3K_2/2 + 3K_1K_2^3/2]\cos(\alpha+\theta)$$
$$+ [K_1K_2 + 3K_1^3K_2/2 + 3K_1K_2^3/2]\cos(\alpha-\theta)$$
$$- [3K_1^2K_2/4]\cos(2\alpha+\theta) - [3K_1^2K_2/4]\cos(2\alpha-\theta)$$
$$- [3K_1K_2^2/4]\cos(2\theta+\alpha) - [3K_1K_2^2/4]\cos(2\theta-\alpha)$$
$$+ [K_1^3K_2/2]\cos(3\alpha+\theta) + [K_1^3K_2/2]\cos(3\alpha-\theta)$$
$$+ [K_1K_2^3/2]\cos(3\theta+\alpha) + [K_1K_2^3/2]\cos(3\theta-\alpha)$$
$$+ [3K_1^2K_2^2/4]\cos(2\alpha+2\theta)$$
$$+ [3K_1^2K_2^2/4]\cos(2\alpha-2\theta)$$

This development is the explanation for sub-frequencies and odd multiple frequencies in the output circuit of a resistance modulator even though the instrument be acted upon by pure waves. These odd frequency components of current may become quite large. Assuming constants of $E = 12$, $r_1 = 80$, $r_2 = 20$, $R_0 = 100$ and $R_x = 100$ where r_1 is associated with the frequency f_1, giving the time angle α and r_2 is associated with the time angle θ, a current i will flow equal to $65.82 - 24.32\cos\alpha - 7.49\cos\theta + 5.71\cos 2\alpha + 0.45\cos 2\theta + 2.98\cos(\alpha+\theta) + 2.98\cos(\alpha-\theta) - 0.72\cos(2\alpha+\theta) - 0.72\cos(2\alpha-\theta) + \ldots$ where the values are in milliamperes.

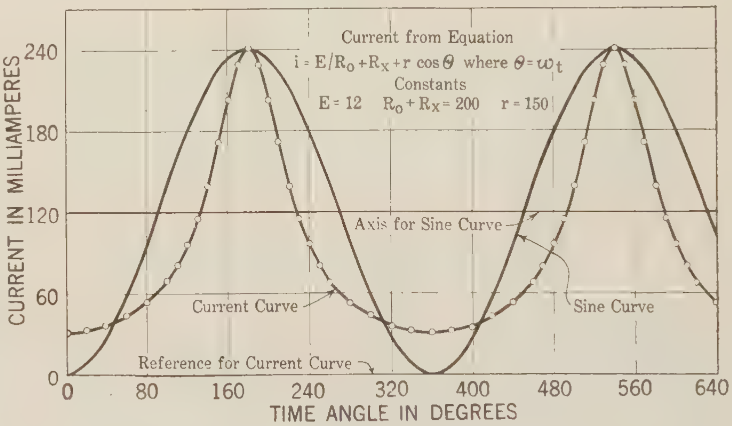

Fig. 1

A particularly valuable feature of mixed frequency modulation analysis is that it offers the possibility of measuring distortion in an actual instrument. By exciting an instrument with two pure waves of known magnitudes and with frequencies prime to each other and measuring one of the combination frequencies in the output and comparing with the calculated value a definite knowledge of what the instrument has done may be gained.

Simple Series Resistance Circuit (Second Development)

Equation

$i = E/(R_0 + R_x + r \cos \theta)$

$= E/R\,[1/(1 + K \cos \theta)]$ where $r/R = K$

Examining for the constant term of a harmonic series:

Constant

$$= E/R \cdot \frac{1}{2\pi} \int_0^{2\pi} d\,\theta/(1 + K \cos \theta) = E/R\,[1/\sqrt{1 - K^2}]$$

Examining for the coefficient of the nth harmonic:

$$A_n = E/R \cdot \frac{1}{\pi} \int_{-\pi}^{\pi} \frac{\cos n\,\theta}{1 + K \cos \theta} \cdot d\,\theta$$

$$= E/R \frac{2\,(-1)^n}{\sqrt{1 - K^2}} \left[\frac{1 - \sqrt{1 - K^2}}{K} \right]^n$$

Writing the series:

$$i = E/R \left\{ (1/\sqrt{1-K^2} - 2/\sqrt{1-K^2} \left[\frac{1-\sqrt{1-K^2}}{K}\right] \cos \theta \right.$$

$$+ \frac{2}{\sqrt{1 - K^2}} \left[\frac{1 - \sqrt{1 - K^2}}{K} \right]^2 \cos 2\,\theta$$

$$- \frac{2}{\sqrt{1 - K^2}} \left[\frac{1 - \sqrt{1 - K^2}}{K} \right]^3 \cos 3\,\theta$$

$$\left. + \ldots \frac{2\,(-1)^n}{\sqrt{1 - K^2}} \left[\frac{1 - \sqrt{1 - K^2}}{K} \right]^n \cos n\,\theta \right\}$$

Sample calculation:

Assumed constants:

R = 200 ohms, r = 80 ohms, and E = 12 volts.

Writing current in milliamperes:

$i = 65.4666 - 27.364788 \cos \theta + 5.719110 \cos 2\,\theta - 1.195278 \cos 3\,\theta + .249818 \cos 4\,\theta - .052216 \cos 5\,\theta + .010912 \cos 6\,\theta - .002281 \cos 7\,\theta + .0004767 \cos 8\,\theta - .00009964 \cos 9\,\theta + .00002082 \cos 10\,\theta + \ldots$

Dropping the constant term and writing the harmonics in per cent of the fundamental:

$i = -100 \cos \theta + 20.90 \cos 2\,\theta - 4.37 \cos 3\,\theta + .914 \cos 4\,\theta - .191 \cos 5\,\theta + .0399 \cos 6\,\theta - .00834 \cos 7\,\theta + \ldots$

Fig. 2 illustrates the manner in which the first three distorting harmonics change relative to the fundamental when modulator and circuit constants remain the same but the degree of modulation, *i. e.*, r, changes. Calculations were based upon the same assumed constants as in the example above with r changing in value from zero to 190 ohms. The latter value represents nearly complete modulation of all resistance in the circuit. Complete modulation is the limit which may be approached. It is interesting to note that if complete modulation could be realized all harmonics would be present and equal in value.

Fig. 3 is similar to Fig. 2. in that it shows the manner of variation of the first three distorting harmonics relative to the fundamental but with R_x, the resistance of the circuit external to the modulator, as the variable and the modulating resistance r held constant at 100.

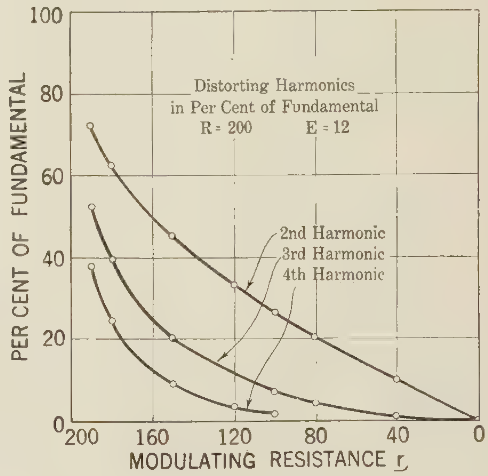

Fig. 2

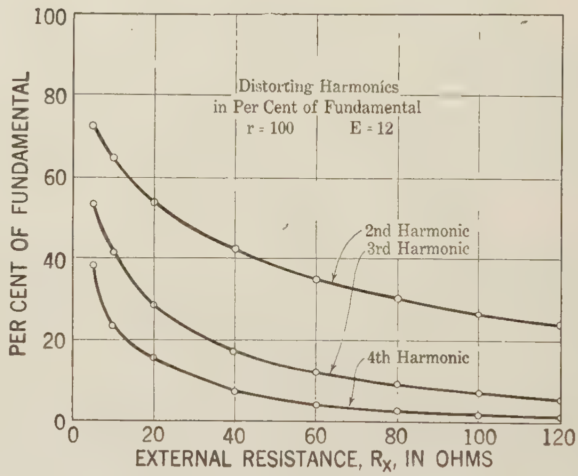

Fig. 3

R_0 is held at 100. As R is the sum of R_0 and R_x it must change. It may be noted that the division of the total circuit resistance between the modulator and the external circuit is of no consequence except that r is limited by R_0.

Diminution Factor in Simple Series Circuits

The equation of the current was found to be:

$$i = E/R \left\{ 1/\sqrt{1-K^2} - 2/\sqrt{1-K^2} \left[\frac{1 - \sqrt{1 - K^2}}{K}\right] \cos \theta \right.$$

$$+ \frac{2}{\sqrt{1 - K^2}} \left[\frac{1 - \sqrt{1 - K^2}}{K} \right]^2 \cos 2\,\theta$$

$$- \frac{2}{\sqrt{1 - K^2}} \left[\frac{1 - \sqrt{1 - K^2}}{K} \right]^3 \cos 3\,\theta$$

$$+ \ldots \frac{2(-1)^n}{\sqrt{1-K^2}} \left[\frac{1-\sqrt{1-K^2}}{K}\right]^n \cos n\,\theta$$

From an examination of the equation it is seen that each succeeding harmonic differs in magnitude from the preceding harmonic by the multiplying factor $[1-\sqrt{1-K^2}]/K$. Since K is the ratio of modulating resistance to the total circuit resistance it is always less than one and approaches one as its limit. Thus the multiplying factor is also always less than one approaching one as its limit and accordingly for the purpose of this discussion has been termed a diminution factor.

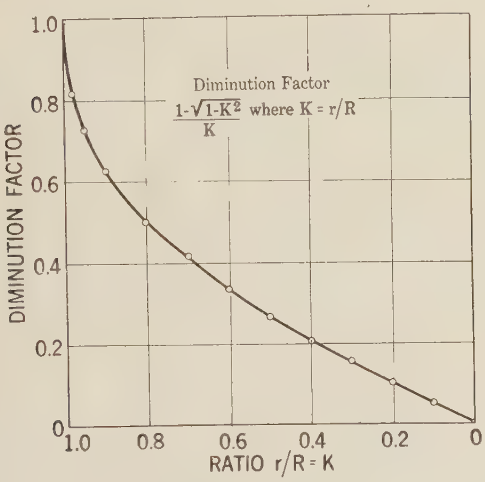

FIG. 4

The factor describes the quality of an operating circuit by giving the magnitude of the second which is the first distorting harmonic relative to the fundamental. The sum of the distorting harmonics compares with the fundamental as $(C + C^2 + C^3 + \ldots C_n)$ compares with one. As the argument of the diminution factor is K the criterion of quality in a circuit is the ratio of r to R. In Fig. 4 the diminution factor has been plotted against the ratio.

TEST CIRCUIT

A circuit of special interest for test purposes, because the direct and alternating components of current are separated, is one consisting of a battery, a heavy inductance unit and a modulator all in series and with a circuit consisting of a large condenser connected in series with a resistance unit in parallel with the modulator. The circuit is shown in Fig. 5. In order to effect an analysis an assumption is made; that no alternating current can flow in the battery circuit because of a preponderately heavy inductance and that no direct current can flow in the receiving circuit because of the condenser. The condenser is made so large that it imposes no appreciable impedance to alternating currents of frequencies dealt with. Although not rigorously true the assumption can be closely approached in a test circuit.

The voltage across the modulator may be written:

$$V_0 + v = (I_0 + i)(R_0 + r\cos\theta)$$

From Kirchoff's law $v = -\,i\,R_x$

Substituting and solving:

$$i = \frac{V_0 - I_0(R_0 + r\cos\theta)}{R_0 + R_x + r\cos\theta}$$

The mean voltage across the modulator may be arrived at in terms of the steady current flowing and the circuit constants. Solving the first equation for v:

$$v = R_x \frac{(V_0 - I_0 R_0) - I_0 r\cos\theta}{R_x + R_0 + r\cos\theta}$$

Summing up v over a complete cycle, setting the result equal to zero and solving for V_0 there results:

$$V_0 = I_0 \{ \sqrt{(R_0 + R_x)^2 - r^2} - R_x) \}$$

The equation for current may be simplified by transformation to:

$$i = \frac{\dfrac{V_0 + I_0 R_x}{R_0 + R_x}}{1 + (r/R_0 + R_x)\cos\theta} - I_0$$

$$= \frac{A}{1 + B\cos\theta} - I_0$$

The form of the equation is the same as that for the series resistance circuit except for a subtracting constant. The same methods may be used to expand it into harmonic series with the same characteristic results as were used for that circuit. Similar relations

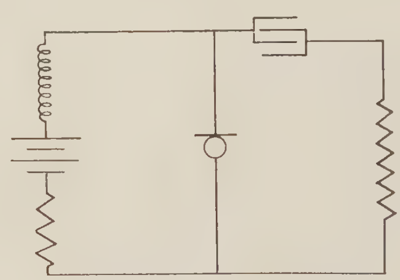

FIG. 5

exist between harmonics. Using the second method the equation for current is:

$$i = \frac{A}{\sqrt{1-B^2}} - I_0 - \frac{2A}{\sqrt{1-B^2}} \frac{(1-\sqrt{1-B^2})}{B} \cos\theta$$

$$+ \frac{2A}{\sqrt{1-B^2}} \frac{(1-\sqrt{1-B^2})^2}{B^2} \cos 2\,\theta + \ldots$$

TABLE OF SYMBOLS

R_0 = Average value of modulator resistance or value about which modulation occurs.
R_x = Resistance of receiver circuit.
R = $R_0 + R_x$.
r = Modulating resistance.

θ = $\omega t = 2\pi f t$ = Time angle in terms of frequency and time.
E = Battery electromotive force.
i = Current in receiving circuit.
α = $\omega t = 2\pi f t$ = Time angle with $f \neq$ to f in θ.
K = r/R.
V_0 = Constant component of modulator voltage.
v = Variable component of modulator voltage.
I_0 = Direct current.
C = Diminution factor = $[1 - \sqrt{1 - K^2}]/K$.

Graphical Determination of Magnetic Fields

Practical Applications to Salient-Pole Synchronous Machine Design

BY ROBERT W. WIESEMAN[1]

Member, A. I. E. E.

Synopsis.—*There are three methods of obtaining the flux distribution in a magnetic field.*

First: By test. Templates or models can be made of the field to be explored and the flux distribution can be obtained by test as described in a companion paper "Graphical Determination of Magnetic Fields—Comparison of Calculations and Tests" by Messrs. E. E. Johnson and C. H. Green.

Second: By mathematical analysis. This method is accurate and consistent results can be obtained. If the problem is very complicated, however, the mathematical solution is very laborious and sometimes impossible.

Third: By the graphical method. This method is quite accurate and it can be used for design calculations. It is comparatively easy and it is the quickest method of the three. The graphical method of plotting magnetic fields used in this paper is described in a companion paper, "Graphical Determination of Magnetic Fields—Theoretical Considerations" by Messrs. A. R. Stevenson, Jr. and R. H. Park.

This paper shows how the graphical flux plots can be used very successfully in design calculations. In fact, the performance characteristic of a salient-pole synchronous machine can not be predetermined accurately without the use of flux distribution coefficients.

* * * * *

Introduction

THE distribution of magnetic flux is a very important factor in the design of electrical apparatus. In order to predetermine the characteristics of an electrical device, it is necessary in many cases to plot the flux distribution around the several parts. This is especially so with salient-pole synchronous machines.

Carter, Rogowski, Lehmann, and others have plotted magnetic fields graphically by drawing the potential and flux lines at right angles and by arranging the tubes of flux so that they form approximate squares with the potential lines. This is naturally a cut-and-try method, but usually the symmetry of the figure and the known conditions enable one to arrive at a correct or balanced plot with only a few trials.

As a rule, it is not difficult to determine if the plot is correct because, with a little practise, the eye can be trained to detect any irregularity in the squares formed by the flux and potential lines. The results obtained by some of the graphical flux plots were found to be in very close agreement with similar results obtained mathematically. Furthermore, the flux distribution data given in this paper have been used very successfully in the design calculations of synchronous machinery by a large manufacturing company for nearly ten years.

I. Magnetic Flux Distribution in a Slot

The first practical application of magnetic flux plotting to dynamo design was done by F. W. Carter in 1901[2]. Carter determined the value of the air-gap coefficient by introducing a fringing coefficient which assumes that all of the fringing flux is confined to a limited area instead of to the entire region over the slot. Carter found this fringing coefficient mainly by the use of the theory of functions of a complex variable to obtain a solution of La Place's equation. In this solution, Carter assumed that the depth of the slot and the width of the tooth were infinite[3].

Calculation of Air-Gap Coefficients from Graphic Flux Plots. Fig. 1 shows the flux distribution in the air-gap over one slot pitch. The line $A\,C\,D$ shows how the flux density varies in the air-gap at the surface of a pole. It is evident that the area $A\,B\,D\,C$ represents the amount of flux which is lost due to the slot. In other words, the effective air-gap is increased by the introduction of a slot and thus the air-gap coefficient (Fig. 1) is equal to the area $A\,B\,D\,E\,F$ divided by the area $A\,C\,D\,E\,F$.

Forty graphical plots were made similar to Fig. 1 with various ratios of slot width to air-gap, slot width to tooth width, and with a ratio of slot depth to slot width equal to four. The air-gap coefficients obtained by these plots are shown in Fig. 2. These curves check

1. A-c. Engineering Dept., General Electric Company.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February, 7-11, 1927.

2. It is claimed that A. Potier in 1889 derived the permeance between a slotted and a plain surface in his study of the electrometer. It can be found in Vol. 2, page 563, of Potier's translation of Maxwell's treatise.

3. A mathematical solution for the finite depth of tooth by Hadamard can be found in the *Annales de Chimie et de Physique*, 1909, Vol. 16, Second Series, page 403.

Carter's work very closely and thus there is practically no difference between the finite and the infinite tooth width and slot depth for open slots which are used in present-day synchronous machines.

Flux Pulsation Due to Armature Slots. The variation in the flux density or the flux pulsation $\left(\frac{BC}{AF}, \text{Fig. 1}\right)$ was obtained from the flux plots

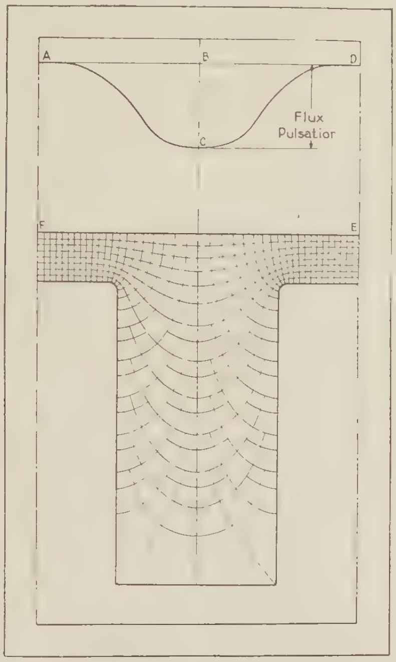

Fig. 1—Flux Distribution in a Slot

$$\frac{\text{Slot width}}{\text{Slot pitch}} = 0.5 \qquad \frac{\text{Slot width}}{\text{Air gap}} = 3.33$$

$$\text{Gap Co-efficient} = \frac{\text{Area } A\ B\ D\ E\ F}{\text{Area } A\ C\ D\ E\ F} = 1.26$$

$$\text{Flux pulsation} = \frac{BC}{AF} = 0.493$$

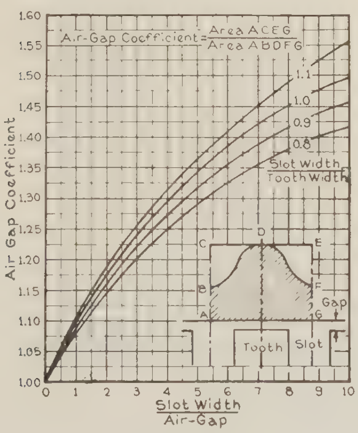

Fig. 2—Air-Gap Coefficient Obtained by Plotting Graphically the Flux Distribution Around a Tooth With Finite Width and Depth as Used in Present Day Machines

where the tooth width equaled the slot width and the results are shown in Fig. 3. This curve also checks Carter's work for the case of the infinite tooth width

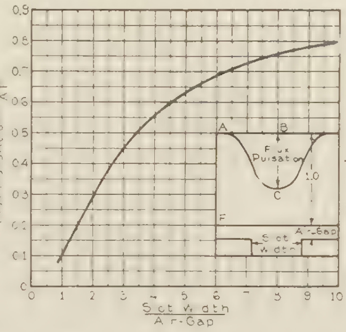

Fig. 3—Magnitude of Flux Pulsation Obtained by Plotting Graphically the Flux Distribution in a Slot With a Finite Width and Depth as Used in Present Day Machines

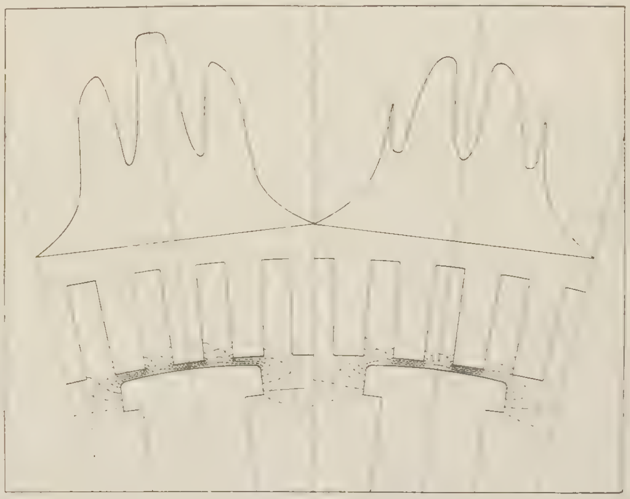

Fig. 4—Flux Distribution at No Load in the Air-Gap of a Salient Pole Synchronous Machine for the Maximum and Minimum Permeance Positions. 10 Per Cent Flux Pulsation

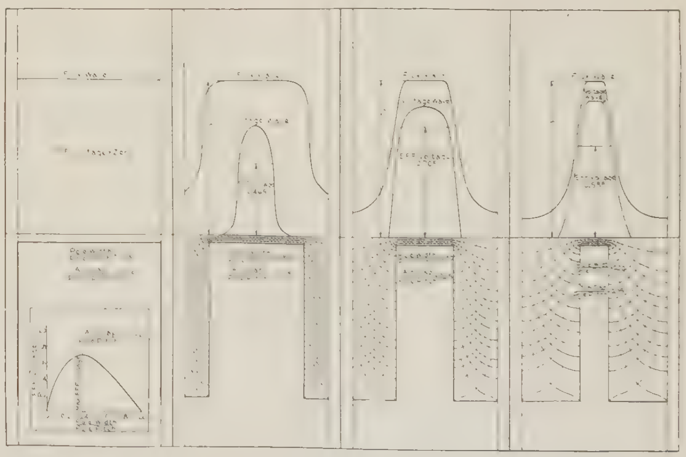

Fig. 5—Magnetic Flux Distribution in Air-Gap of Inductor Alternator Pole Width for Maximum Effective Voltage at No-Load

and slot depth. The flux pulsation caused by the armature slots produces a loss in the pole face. This loss is part of the open circuit core loss, and it can be

calculated when the magnitude of the flux pulsation is known.

If the number of teeth spanned by a pole varies when the pole moves through a tooth pitch, the pole flux will pulsate if the pole has no low impedance damper winding, etc. Fig. 4 shows a 10 per cent flux pulsation

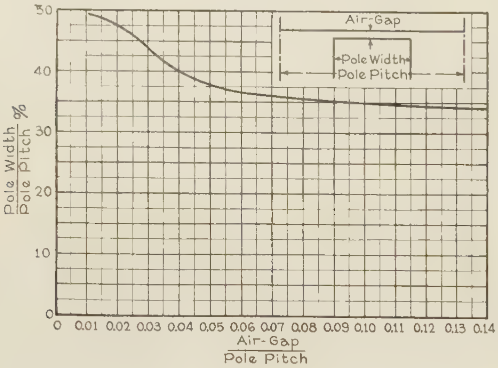

Fig. 6—Inductor Alternator Pole Width for Maximum Effective Voltage at No Load

from the maximum to the minimum permeance positions in a machine which has a small number of wide stator slots and a small air-gap. This flux pulsation, if excessive, will increase the open circuit core loss and it may produce a magnetic noise. If the teeth are not spiralled, therefore, it is always desirable to have the number of teeth over the pole a constant, especially if a small number of teeth per pole is used.

Inductor Alternator Pole Width Which Gives the Maximum Effective Voltage. There seems to be an increasing demand for high frequency generators for supplying power to induction furnaces, and high-speed tools, for testing, and for experimental work. Usually if the frequency is above 2500 cycles per second, the inductor type alternator is used.

The voltage induced in an armature coil of an inductor alternator depends upon the flux pulsation, as shown in Fig. 5. If the pole width is 100 per cent of the pole pitch, and if the air-gap is uniform, the flux wave will be a rectangle, and, obviously, the flux pulsation and the induced voltage will be zero. As the pole width is decreased, Fig. 5, the flux pulsation increases. The effective value of the induced voltage, however, increases until it reaches a maximum, and as the pole width is further decreased, the effective voltage decreases. Thus it is very desirable to shape the pole of an inductor alternator so that the voltage induced in the armature coil is a maximum. The insert in Fig. 5 shows how the effective voltage varies with the pole width when the air-gap is five per cent of the pole pitch. In this case the maximum effective voltage at no load occurs when the pole width is 38 per cent of the pole pitch. A number of these flux plots were made for various ratios of air-gap to pole pitch and the corresponding maximum effective voltages were obtained and plotted in Fig. 6. It can be seen that a pole width equal to half of the pole pitch should be used only when the air-gap is infinitely small. For a 10 per cent air-gap, the pole width should be 0.35 of the pole pitch to give the maximum effective voltage at no load. Under load the maximum effective voltage should occur when the pole pitch is a little less than given by the curve in Fig. 6.

II. Magnetic Flux Distribution in the Air-Gap of a Salient-Pole Synchronous Machine at No Load When Excited Only by the Field Coils

Fig. 7 shows the flux distribution around the pole at no load when a salient-pole synchronous machine is excited by its field coil. The full line flux wave was calculated from the flux plot at the surface of the armature and the dotted flux wave was obtained by test with an exploring conductor placed on the surface of the armature. The flux wave fundamental is 1.11 times the maximum value of the flux wave and the flux wave third harmonic is 0.085 times the maximum value of the fundamental.

Fundamental and Third Harmonic in the Air-Gap Flux Wave at No Load. Seventy-five hypothetical flux plots at no load were made of poles used in present-day machines whose pole faces were arcs of circles.

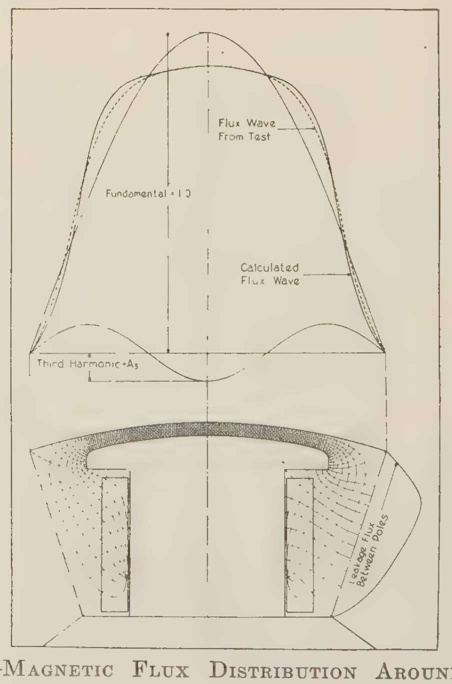

Fig. 7—Magnetic Flux Distribution Around a Pole at No Load When a Salient-Pole Synchronous Machine is Excited by its Field Winding

The pole shapes used are included in the limits of the following three variables:

$$\frac{\text{Minimum Gap}}{\text{Pole Pitch}} \quad \text{from 0.01 to 0.05}$$

$$\frac{\text{Pole Arc}}{\text{Pole Pitch}} \quad \text{from 0.050 to 0.75}$$

$$\frac{\text{Maximum Gap}}{\text{Minimum Gap}} \quad \text{from 1 to 3}$$

The flux waves were analyzed for their fundamentals

and third harmonics, the values of which are shown in Figs. 8 and 9. In Fig. 8, the fundamental A_1 of the flux wave is expressed as a decimal fraction of the maximum value of the flux wave which is taken as unity. In Fig. 9, the third harmonic A_3 of the flux wave is expressed as a decimal fraction of the fundamental which is taken as unity. The polarity of the third harmonic is also given and it is considered minus when it is as shown in the insert of Fig. 9. The pole shape, which will have a flux wave with a zero third

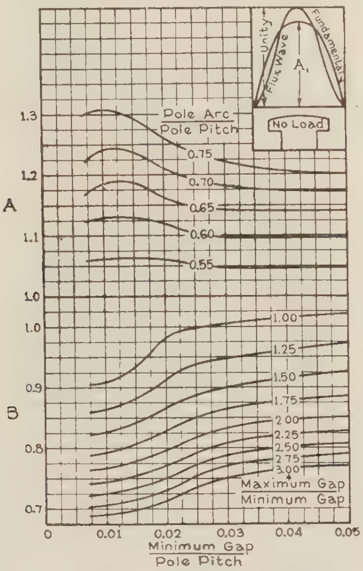

FIG. 8—FUNDAMENTAL OF THE NO-LOAD FLUX WAVE IN THE AIR-GAP OF A SALIENT-POLE SYNCHRONOUS MACHINE

Maximum value of actual flux wave equals unity
Fundamental $A_1 = A \times B$

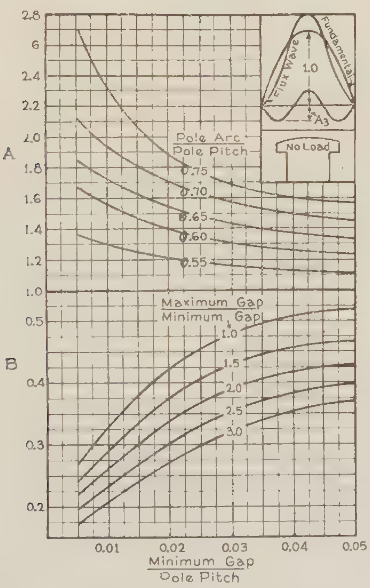

FIG. 9—THIRD HARMONIC OF THE NO-LOAD FLUX WAVE IN THE AIR-GAP OF SALIENT-POLE SYNCHRONOUS MACHINE

Maximum value of fundamental equals unity
Third harmonic $A_3 = A \times B - 0.6$

harmonic, can also be obtained from Fig. 9. For example, if the ratio of the minimum gap to the pole pitch is 0.02, and if the ratio of the maximum to the minimum gap is 1.5, then the ratio of the pole arc to the pole pitch should be 0.67 to obtain a flux wave at no load which has no third harmonic.

Calculation of the Open Delta Voltage and the Delta Circulating Current of a Synchronous Machine at No Load. A very interesting application of the flux wave third harmonic curves, Fig. 9, is the calculation of the voltage which appears at no load at the open corner of a delta-connected armature winding whose coils do not have a two-thirds pitch. It is well known that only the third harmonic or multiples of the third harmonic voltage can appear at the open delta. Since the multiples of the third harmonic flux wave are usually small, and since both the armature coil pitch and distribution further decrease the voltage produced by these flux multiple third harmonics, the multiple third harmonic voltages can be neglected. Thus, the calculation of the third harmonic voltage at the open corner of a delta-connected armature winding is very simple, if the amplitude of the flux third harmonic is known.

Let

E = Normal phase voltage of the armature winding at no load

A_3 = Amplitude of the flux wave third harmonic expressed as a decimal fraction of its fundamental Fig. 9

k_p = Armature coil pitch coefficient for the fundamental

k_d = Armature coil distribution coefficient for the fundamental

k_{3p} = Armature coil pitch coefficient for the third harmonic

k_{3d} = Armature coil distribution coefficient for the third harmonic

E_3 = Open delta voltage (third harmonic)

then

$$E_3 = 3 E A_3 \frac{k_{3p} \, k_{3d}}{k_p \, k_d}$$

This method of calculating the third harmonic delta voltage assumes that there is no saturation in the magnetic circuit and it ignores the effect of the stator and the rotor slots. These factors, however, are quite small in most machines. The three-phase machine whose pole shape is shown in Fig. 7 had 18 slots per pole, armature coil pitch 0.777, ratio of minimum gap to pole pitch 0.037, ratio of pole arc to pole pitch 0.674, ratio of maximum to minimum air-gap 1.22, and phase voltage of 3810 volts.

Thus

$$k_p = 0.939 \quad k_d = 0.955$$
$$k_{3p} = 0.49 \quad k_{3d} = 0.646$$

From

$$\text{Fig. 9, } A_3 = 1.44 \times 0.475 - 0.6 = 0.084$$

therefore

$$E_3 = 3 \times 0.084 \times 3810 \frac{0.49 \times 0.646}{0.955 \times 0.939} = 339 \text{ Volts}$$

$$E_3 \text{ by test } = 300 \text{ Volts}$$

The delta circulating current at no load is

$$I_3 = \frac{E_3}{\text{Third harmonic synchronous impedance}}$$

Calculation of Air-Gap Ampere-Turns, Using the Flux Distribution Coefficients K_ϕ and K_λ. In order to predetermine the no-load air-gap ampere-turns accurately for a pole whose pole arc radius is less than the radius of the armature face, two flux distribution coefficients must be obtained. It is well known that if the flux wave has a flat top, more flux (lines per pole) is required to give a certain effective voltage at the terminals of the armature winding than for a peaked flux wave. In order to obtain the flux per pole accurately, therefore, it is necessary to modify the flux equation which assumes a sinusoidal flux distribution and to introduce the flux distribution coefficient[4] K_ϕ which is the ratio of the area of the actual no load flux wave to the area of its fundamental.

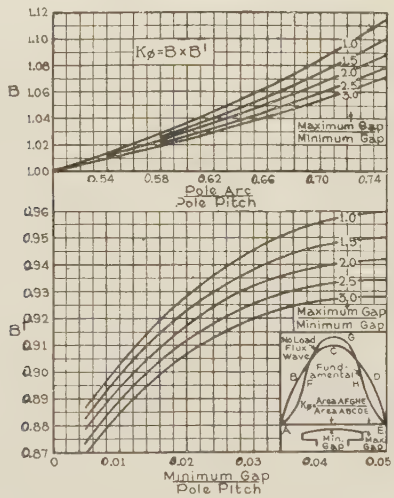

Fig. 10—Flux Distribution Coefficient K_ϕ

Messrs. Doherty and Shirley introduced this flux coefficient K_ϕ in 1918[4], and they obtained the values of K_ϕ from flux distribution plots (see Fig. 36 of Messrs. Doherty and Shirley's paper) which assumed that the flux density varied inversely as the distance (in a straight line) from the pole face to the armature core. This, of course, is an approximate solution of the problem. Fig. 10 gives the values of K_ϕ which were obtained from the 75 hypothetical flux plots similar to Fig. 7 where the flux distribution was obtained by actually plotting the tubes of flux. These values of K_ϕ practically check the values of K_ϕ given in Messrs. Doherty and Shirley's paper.

The introduction of K_ϕ thus gives the actual flux per pole for any flux wave. The next step is to find the average air-gap density over the pole face in order to find the necessary ampere turns to force this flux across the air-gap. It is very convenient to know the flux which passes directly out from the pole and into the armature, as shown by the shaded area, in the insert of Fig. 11. This flux is equal to K_λ times the flux per pole where K_λ is the ratio of the area $G\ B\ C\ D\ F$ to the area $A\ B\ C\ D\ E$ in Fig. 11. The average air-gap density over the pole (Region $G\ F$, Fig. 11) is K_λ times

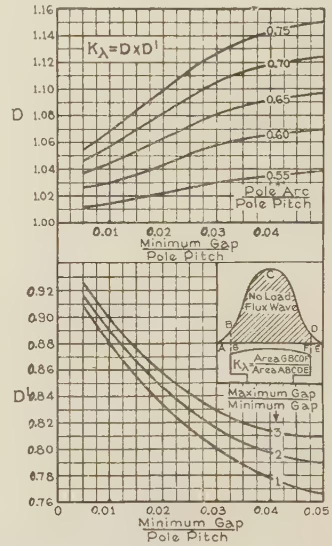

Fig. 11—Pole Face Flux Coefficient K_λ

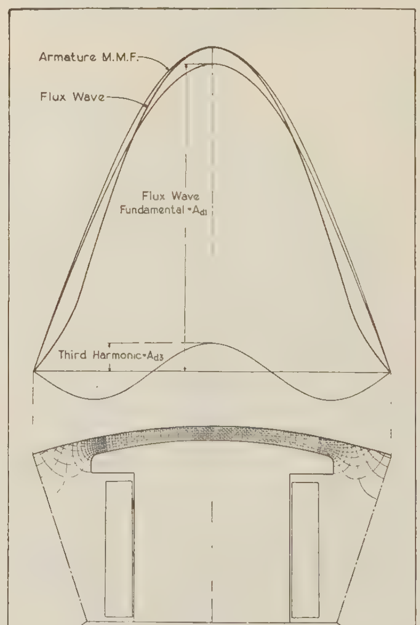

Fig. 12—Magnetic Flux Distribution in the Air-Gap When a Salient Pole Synchronous Machine is Excited Only by a Sine Wave Armature M. M. F. Whose Axis Coincides With the Pole Center

the flux per pole divided by the area of pole face. The air-gap ampere turns can now be obtained accurately since the air-gap coefficient, Fig. 2, and the reluctance of the air-gap are known.

The two flux distribution coefficients K_ϕ and K_λ, calculated from the predetermined flux wave, made

4. *Reactance of Synchronous Machines and Its Application*, Doherty and Shirley, A. I. E. E., Trans. Vol. XXXVII, p. 1209.

it possible to predetermine very closely the performance characteristics of a two-speed salient-pole synchronous motor[5]. This two-speed motor had irregular shaped poles arranged in pairs whose flux waves deviated appreciably from a sine wave at either speed.

Calculation of the Leakage Flux of a Salient-Pole Synchronous Machine. The flux distribution curve of the leakage flux between poles is shown in Fig. 7. This curve is plotted on the interpolar center line and it neglects the small amount of leakage flux in the lower corner of the pole. The ratio of the area under the leakage flux distribution curve to the area under the main flux distribution curve in Fig. 7 plus 1 gives the leakage coefficient which is 1.16 for this pole. This coefficient should be increased slightly to allow for the small end leakage flux.

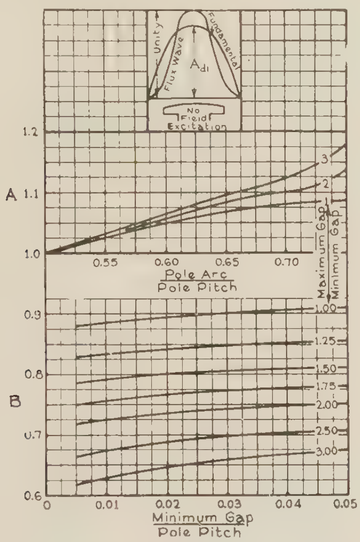

Fig. 13—Fundamental of the Air-Gap Flux Wave When a Salient Pole Synchronous Machine is Excited by Only a Sine Wave Armature M. M. F. Whose Axis Coincides with the Pole Center

Maximum value of actual flux wave equals unity
Fundamental $A_{d1} = A \times B$

III. Magnetic Flux Distribution in the Air-Gap When a Salient-Pole Synchronous Machine is Excited Only by a Sine Wave Armature Magnetomotive Force Whose Axis Coincides With the Pole Center

Fig. 12 shows the flux distribution in the air-gap when a salient-pole synchronous machine is excited only by a sine wave armature magnetomotive force whose axis coincides with the pole center. The abrupt break in the spacing of the flux lines is simply a change in scale for convenience in plotting and for allowing more flux lines to be drawn in the interpolar space. The armature flux wave in Fig. 12 is peaked while the field flux wave, Fig. 7, for the same machine is decidedly flat topped. The peaked flux wave in Fig. 12 is the flux wave which balanced polyphase armature currents tend to produce at zero power factor. The flux wave fundamental, Fig. 12, is 0.94 times the maximum value of the flux wave and the flux wave third harmonic is 0.092 times the maximum value of the fundamental.

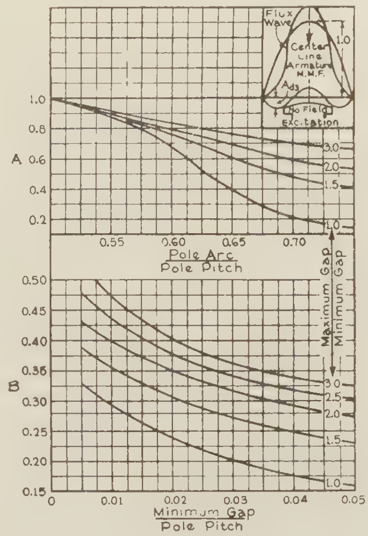

Fig. 14—Third Harmonic of the Air-Gap Flux Wave When a Salient-Pole Synchronous Machine is Excited Only by a Sine Wave Armature M. M. F. Whose Axis Coincides with the Pole Center

Maximum value of fundamental equals unity
Third harmonic $A_{d3} = - A \times B$

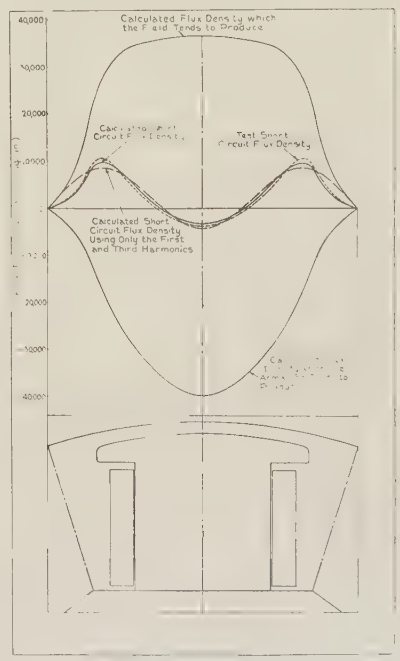

Fig. 15—Flux Distribution at Sustained Short Circuit in the Air-Gap of the Machine Shown in Figs. 7 and 12.

Calculation of the Fundamental and the Third Harmonic in the Flux Wave Which Polyphase Armature Currents Tend to Produce at Sustained Short Circuit. Seventy-five hypothetical flux plots were made similar to Fig. 12 for the same range of pole shapes as previously

5. *A Two-Speed, Salient-Pole Synchronous Motor*, R. W. Wieseman, A. I. E. E., Trans. Vol. XLIV, p. 436, 1924, Figs. 15, 16, 17, 18.

described. These armature flux waves were analyzed for their fundamentals and third harmonics, the values of which are shown in Figs. 13 and 14. In Fig. 13, the fundamental A_{d1} is expressed as a decimal fraction of the maximum value of the flux wave which is taken as unity. In Fig. 14, the third harmonic A_{d3} is expressed as a decimal fraction of the fundamental which is taken as unity.

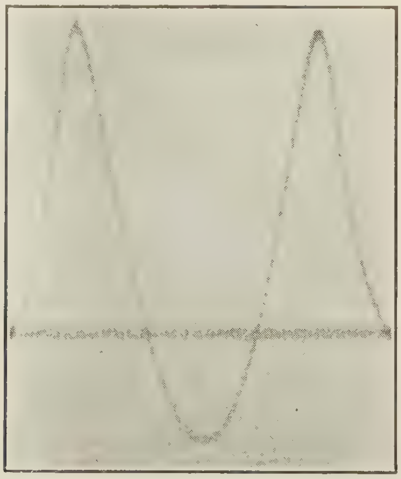

FIG. 16—VOLTAGE INDUCED IN EXPLORING CONDUCTOR PLACED IN THE AIR-GAP OF A SALIENT-POLE MACHINE AT SUSTAINING POLYPHASE SHORT CIRCUIT

Predetermination of the Flux Wave in the Air-Gap of a Salient-Pole Synchronous Machine at Sustained Polyphase Short Circuit. When a polyphase salient-pole generator is short-circuited, the armature m. m. f. is in opposition to the field m. m. f. If the armature resistance is neglected, the sustained air-gap short-circuit flux, which travels in synchronism with the pole, can be obtained readily by subtracting the armature flux wave in Fig. 12 from the field flux wave, Fig. 7. This short-circuit wave is shown in Fig. 15. Fig. 16 shows the actual short-circuit flux wave obtained with an exploring conductor placed on the armature surface and this wave is also plotted in Fig. 15. The flux wave, Fig. 16, must include such flux waves which are not in synchronism with the pole and, therefore, this wave must be slightly different from the calculated flux wave in Fig. 15.

Calculation of the Stray Core Loss in the Armature Teeth of a Salient-Pole Synchronous Machine at Sustained Polyphase Short Circuit. The short-circuit flux wave can be predetermined approximately by combining the fundamentals and third harmonics of the field flux waves, Figs. 7, 8, and 9, with the armature flux waves, Figs. 12, 13, and 14. Fig. 15 shows the short-circuit flux wave obtained by this method. The stray core loss in the armature teeth of a salient-pole machine at sustained polyphase short circuit can now be predetermined. The problem can be simplified by neglecting the fundamental which is usually small and using only the resultant third harmonic flux.

The full-load flux wave of a synchronous condenser at zero power factor either over or under excited can also be predetermined by this method.

IV. MAGNETIC FLUX DISTRIBUTION IN THE AIR-GAP WHEN A SALIENT-POLE SYNCHRONOUS MACHINE IS EXCITED ONLY BY A SINE-WAVE ARMATURE MAGNETOMOTIVE FORCE WHOSE AXIS IS IN QUADRATURE WITH THE POLE CENTER

Fig. 17 shows the flux distribution in the air-gap when a salient-pole machine is excited only by a sine wave armature m. m. f. whose axis is in quadrature with the pole center. The effect of saturation and of the stator and rotor slots is neglected. The armature flux wave is made up principally of a fundamental and a large third harmonic. The flux wave fundamental is 0.54 times the maximum value of the armature m. m. f., and the flux wave third harmonic is 0.43 times the maximum value of the fundamental.

Seventy-five hypothetical flux plots similar to Fig. 17 were made of the air-gap flux which the armature currents tend to produce when the armature m. m. f. is in quadrature with the pole center. These flux

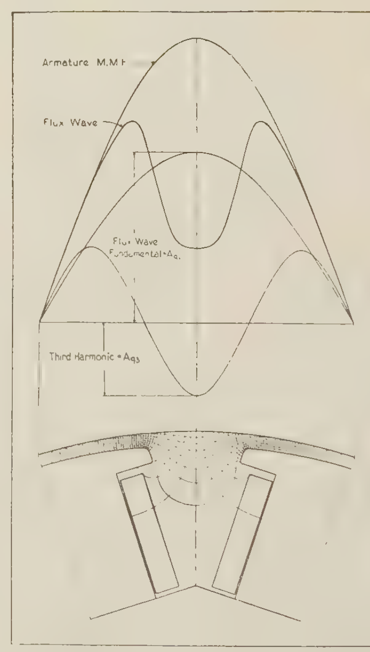

FIG. 17—MAGNETIC FLUX DISTRIBUTION IN THE AIR-GAP WHEN A SALIENT-POLE SYNCHRONOUS MACHINE IS EXCITED BY ONLY A SINE-WAVE ARMATURE M. M. F. WHOSE AXIS IS IN QUADRATURE WITH THE POLE CENTER

waves were analyzed for their fundamentals and third harmonics, the values of which are shown in Figs. 18 and 19. In Fig. 18, the armature flux fundamental A_{q1} is expressed as a decimal fraction of the armature sine wave m. m. f., which is taken as unity. This method of evaluating the armature flux fundamental is done for convenience in design calculations. In Fig. 19, the armature flux third harmonic A_{q3} is ex-

pressed as a decimal fraction of the armature flux fundamental which is taken as unity.

Calculation of Displacement Angle of a Salient-Pole Synchronous Machine. It is well known that an a-c. generator rotor leads its voltage, and a synchronous

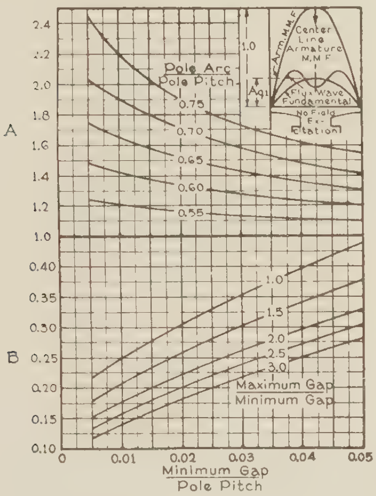

FIG. 18—FUNDAMENTAL OF THE AIR-GAP FLUX WAVE WHEN A SALIENT-POLE SYNCHRONOUS MACHINE IS EXCITED BY ONLY A SINE WAVE ARMATURE M. M. F. WHOSE AXIS IS IN QUADRATURE WITH THE POLE CENTER

Maximum value of armature m. m. f. equals unity
Fundamental $A_{q1} = A \times B$

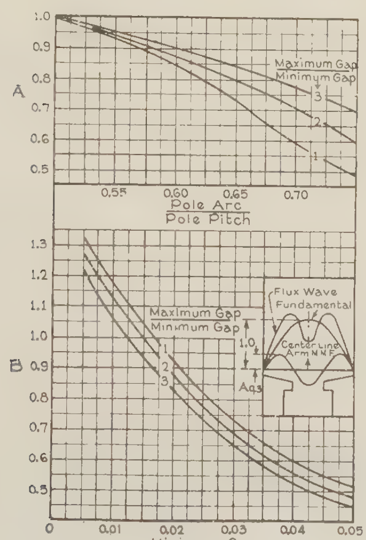

FIG. 19—THIRD HARMONIC OF THE AIR-GAP FLUX WAVE WHEN A SALIENT-POLE SYNCHRONOUS MACHINE IS EXCITED BY ONLY A SINE WAVE ARMATURE M. M. F. WHOSE AXIS IS IN QUADRATURE WITH THE POLE CENTER

Maximum value of armature flux fundamental equals unity
Third harmonic $A_{q3} = A \times B$

motor rotor lags behind the line voltage. The power or displacement angle of lead or lag is caused by the armature flux distorting the field flux. The fundamental A_{q1} which can be obtained from Fig. 18 is thus a measure of this distortional effect[6]. The harmonics of the armature flux have no distortional effect on the field flux fundamental, and since the harmonics of the field flux are usually small, the displacement angle can be obtained by combining properly the armature flux fundamental A_{q1} with the field flux fundamental A_1.

Furthermore, by combining the fundamentals and third harmonics A_1, A_3, A_{d1}, A_{d3}, A_{q1}, and A_{q3}, which can be readily obtained from Figs. 8, 9, 13, 14, 18, and 19, the air-gap flux wave of a salient-pole synchronous machine can be approximated for any load condition.

Additional practical applications of plotting magnetic flux distribution curves will be given in a future paper.

The author gratefully acknowledges the assistance of Mr. L. P. Shildneck in plotting some of the flux distribution curves.

BLAMES 15 PER CENT OF U. S. INDUSTRIAL ACCIDENTS ON POOR LIGHTING

Between fifteen and twenty per cent of all industrial accidents in the United States are caused by inadequate lighting, which means that poor light in factories is costing the country hundreds of thousands of accidents and tens of millions of dollars in losses every year, declares Arthur E. Carruthers, Editor of *Safety Engineering.*

"Darkness and imperfect illumination have always been accident-causing hazards, and illumination will always be the safety measure which eliminates these hazards," he says.

"The human eye needs proper illumination to serve us with safe eyesight, and there is especial need of correct illumination in an industrial plant. It is there that men are busy, their attention on their work, and where they are surrounded with conditions which, unless clearly and perfectly discernable, become accident-causing hazards.

"No matter where it may be, in the factory, in the store, down in the mine or in the hold of a ship, good illumination must be there if tasks are to be performed safely."

Too many employers have failed to give proper attention to the lighting of work places, says Mr. Carruthers, because they do not realize the effect of light, good or bad, upon production, waste, quality of output, spoilage, and the eye-sight and morale of their employes.—*Utility Bulletin,* of the New York State Committee on Public Utility Information, February 7, 1927.

6. *Synchronous Machines, Part I, An Extension of Blondel's Two-Reaction Theory,* by Messrs. Doherty and Nickle, A. I. E. E. October JOURNAL, 1926, p. 974.

Abridgment of

Voltage Standardization of A-C. Systems

From the Viewpoint of the Electrical Manufacturer

BY F. C. HANKER[1]
Member, A. I. E. E.

and

H. R. SUMMERHAYES[2]
Member, A. I. E. E.

Synopsis.—*In outlining the history of voltage standardization, it is observed that there has been separate standardization of voltages of various types of apparatus, rather than standardization of a complete operating system. The results of a questionnaire answered by 22 operating companies are analyzed and the conclusion is drawn that the use of the old standard transformer voltages involved, in many cases, over-exciting the transformers or generators in order to maintain satisfactory voltage at the consumers' terminals. The reason is that the existing transformer voltage standards do not compensate for the line drop in transmission lines and feeders. The voltage standards of the International Electrotechnical Commission are set forth, indicating a partial agreement as to maximum system voltages with the proposed standards, although arrived at by a different method. The I. E. C. standardization, however, is not so complete as the proposed system.*

In describing the proposed standards, certain basic principles are laid down as the conditions which must be fulfilled.

The proposed system of voltage standards starts with already standardized utilization voltages at the low end of the scale and suggests tranformer voltage ratings and ratios which will allow proper voltage to be supplied to the consumers without over-exciting any of the transformers or generators in the system, and ties in the transformer and apparatus voltages with system voltages, based on the A. I. E. E. definition of rated circuit voltages. The proposed standards thus cover the whole field of voltages of a-c. apparatus of all kinds and harmonize them with system voltages in such a way that all reasonable operating requirements may be met.

The salient features of the proposed standardization are as follows:

The system voltage is the same as the highest rated voltage of transformers supplying the system; it thus corresponds to the A. I. E. E. rated circuit voltage and fixes test voltage on all apparatus used on the system.

Step-down transformer secondary voltages from 115 volts up to 69,000 volts will be multiples of 11.5, excepting transformers supplying 2400-volt systems, which will be rated 2400 volts. Thus, typical step-down transformers will deliver

460 volts
6,900 volts
23,000 volts
69,000 volts

For higher voltages, step-down transformers will have secondary voltages in multiples of 11, thus:

88,000 volts
110,000 volts
132,000 volts
154,000 volts

complying with well established practise.

In order to enable the step-down transformers to deliver these voltages, their primaries will be rated in multiples of 11, thus:

6,600,
22,000, etc., up to 66,000 and above that

multiples of 10½, thus:

105,000
126,000
210,000, etc.

Step-up transformers, excepting the 2400-volt class, will have their high-tension windings rated in multiples of 11½ up to 69,000, and multiples of 11 above that, whereas their low-tension winding will be rated 5 per cent lower than the system voltages or generator voltages.

Thus, step-up and step-down transformers will not be interchangeable, but each will have the proper ratio for its purpose. To make them interchangeable would require 25 per cent range, which would involve too great an expense if applied to all transformers. Transformers of 25 per cent range may be required in many cases where power flows in either direction but such transformers should be of special design and this extra cost should not involve the whole line of transformers. The tabulation of voltages gives also the present manufacturers, standards for apparatus voltages, such as oil circuit breakers, disconnecting switches, etc. These standards for 88,000 volts and above correspond to the system voltages of multiples of 11. Below 88,000 volts they are somewhat higher than the recognized system voltages given in the tabulation in order to meet existing conditions in these lower voltages. The tabulation also gives motor voltages in multiples of 11, while the generator voltages, in order to allow for line drop, are multiples of 12 up to 2400 volts, and multiples of 11½ from 6900 volts up.

The last section of the paper gives a discussion of the economic advantages of voltage standardization, indicates the magnitude of the investments involved, and gives a general idea of the savings which may be made by standardization.

Introduction

THE lack of a logical and coordinated voltage standardization of apparatus extending from the initial supply to the utilization device has resulted in an unnecessary expense to the industry. Standardization up to this time has been largely a matter of individual efforts on segregated types of apparatus. The result has been that while standards have been developed for the several types of apparatus, it is generally conceded that these do not harmonize in such a manner that standard apparatus can be coordinated readily into a complete operating system. For this reason there has been a considerable tendency for the users of apparatus to buy equipment of special voltage ratings to suit their own particular conditions. Since these conditions would naturally vary somewhat from operator to operator, the special apparatus ordered by them does not constitute a new but unofficial line of standards, but a truly special line of apparatus for each operating company.

Considerable attention has been given to this tendency to deviate from the established standards recognized by the A. I. E. E., N. E. L. A., and Electric Power Club, since although the use of special apparatus

1. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
2. General Electric Co., Schenectady, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

might be advantageous from the point of view of the individual operator, it nevertheless places a burden on the industry as a whole, including those purchasers who believe they are being supplied with special apparatus at standard price. Users of standard apparatus help to bear this as well as the users of special apparatus, since the development costs and extra supervision and manufacturing costs caused by the production of specials tend to raise the cost of standard apparatus. The special tools often required for the production of specials also raise the investment in manufacturing plant, and this extra cost is usually borne by the standard as well as by the special product. Furthermore, special apparatus entails longer deliveries both on the initial apparatus and on renewal and repair parts.

Purpose

This paper is to present the viewpoint of the manufacturers on voltage standardization, and its purpose in greater detail is:

1. To outline the history of voltage standardization, pointing out that it has been separate standardization of various types of apparatus rather than standardization of a complete operating system.
2. To show by the results of a questionnaire how representative operating practise lines up with the existing standards.
3. To discuss the need for standardization of the complete system and the conditions which such a standardization must meet.
4. To present what is believed to be a workable set of standards which meet these conditions and to demonstrate their application to a typical system.
5. To discuss the advantages of standardization from the manufacturer's viewpoint and to indicate the benefits accruing to the industry as a whole.

History

As indicated in the introductory matter, progress in the voltage standardization of the complete a-c. electrical operating system, including generation, transmission, distribution, and utilization, has been largely a matter of the standardization of the several divisions of apparatus rather than a concerted standardization of the whole operating system.

High-voltage standardization dates back to 1899, when the Standardization Rules of the A. I. E. E. recommended that the rated circuit voltage should be measured at the receiving end and that the recommended values should be 1000, 2000, 3000, 6000, 10,000, 15,000, and 20,000 volts. In order to take care of line drop, generators were to be rated at 1150, 2300, and 3450 volts, thus allowing a total transmission regulation of 15 per cent.

The recommended voltages were extended in the 1902 Standardization Rules to include 30,000, 40,000, and 60,000 volts in order to keep up with progress in high-voltage transmission, the voltage still being measured at the receiving end.

The 1911 Standardization Rules made a sweeping revision in that it was decided to measure the circuit voltage at the sending end. The recommended voltages were no longer based on multiples of 10, but on multiples of 11, and the list was extended to include 88,000 and 110,000 volts. It was also recommended that transformers should transform between the listed voltages and that their ratios should be exact multiples of five. Since that time high voltages have always been measured at the secondary of the sending end transformers and have remainded on a basis of multiples of 11, although extensions and additions have been made to the recommended list.

In 1914 the manufacturers of a-c. motors, standardized motor voltages at 110, 220, 440, 550, and 2200 volts, with allowable variations of 10 per cent above and below normal.

Thus the trend in a-c. systems is quite definitely toward the use of 115-volt lamps, with 120-volt lamps a close second.

What utilization voltage standardization had been accomplished by 1921 has been reviewed above, and may be summarized by:

Motors: Multiples of 110 volts, but will operate successfully on variations of $\pm$ 10 per cent in the supply.

Lamps: 110-, 115-, and 120-volt, the 115-volt predominating.

Appliances: No standardization.

The existing distribution transformer voltage standard was the triple rated 100-, 115-, 120-volt secondary. The great majority of these distribution transformers were of the 20:1 ratio, 2300-volt class, without taps in the primary, giving 240/230/220-120/115/110 on the secondary when suitably excited on the primary.

The average regulation between the transformer secondary and the service switch was found to be two per cent, and between the service switch and the utilization device one per cent for lamps and possibly double that for motors.

After considerable discussion between the Subcommittee, the Lamp Committee, and the member operating companies, it was tentatively recommended in the 1921 and 1922 Reports of the N. E. L. A. Electrical Apparatus Committee, that the standard service voltage be such that the proper average voltage would be supplied to 115-volt lamps, with recognized departures for supplying the proper average voltage to 110-volt and 120-volt lamps, the latter being for only existing systems of that voltage. With any of these average service voltages it was intended to use 110-volt motors and electric household appliances having a voltage rating covering a range of from 110 to 120 volts, since these two classes of apparatus do not require the close correspondence between impressed voltage and normal rated voltage which lamps require for economical operation.

This scheme fitted in fairly well with existing dis-

tribution transformer voltages, except that on systems requiring 120 volts at the lamp socket the voltage at the transformer secondary must be between 123 and 124 volts to allow for the drop between transformer and lamp, and hence the excitation voltage impressed on the primary must be of the order of 2500 volts. This would work the iron rather heavily.

There was also some question raised as to the successful operation of 110-volt motors when the average service voltage was such that the average impressed voltage was 120 volts, since this average feature implied that at times the impressed voltage might be two or three volts above 120 and thus exceed the 10 per cent tolerance allowed in the Electric Power Club rule. Operating companies stated they had never experienced any trouble of this nature, however, and the report remained on the basis of 110-volt motors.

It was recognized that the standardization of service voltage would be possible and of value only if it could be coordinated with the rest of the system all the way back to the generator. Accordingly, the final disposition of the Subcommittee report was that it was recommended in 1923 to be brought to the joint attention of the A. I. E. E., Electric Power Club, and N. E. L. A., with the idea that these agencies might cooperate in the future toward the voltage standardization of the electrical system from generator to utilization device.

The causes which produced these conditions became the object of an investigation by the Transformer Subcommittee of the N. E. L. A. Electrical Apparatus Committee in 1925. By means of a questionnaire to representative operating companies they inquired into the actual operating voltage at each point in a complete system, in an effort to find out what apparatus ratings would be best suited to operating conditions, to what degree existing apparatus standards would suffice, and what changes would be necessary in order that operating companies would find it to their advantage to buy apparatus conforming to a new set of standards rather than to buy special apparatus. The questionnaire inquired specifically into the voltage ratings of all generators and transformers on the system, the tap voltage rating used on the transformers, the actual operating voltage at the generators and on the primary and secondaries of all transformer banks and at the service switch, for conditions of light and maximum load and on the longest feeder and the shortest feeder, and the range of feeder induction voltage regulators, if used.

Replies were received from 22 power companies, representing the two cases: (a) systems where the feeders were fed directly off the generator bus at generator voltage and the stepping down to service voltage accomplished through two or more transformations, and (b) systems where transmission at high voltage intervenes between the generator bus and the distribution system. While there were several discrepancies in the figures submitted, it was felt nevertheless that in the main they were reliable and representative of general practise.

The salient points which the questionnaire developed were as follows:

1. Eleven of the twenty-two companies had transformers on their system over-excited by more than five per cent above the connected tap rating. In five cases this over-induction was 10 per cent or more above the connected tap rating.

2. Three companies reported their generators to be operating at more than five per cent above their normal rating, the maximum being nine per cent above normal. Thirteen of the remaining companies operate their generators above normal but not more than five per cent above the normal voltage rating.

3. Whereas feeder induction voltage regulators were required to operate at greater buck than boost in five cases in order to maintain satisfactory service voltage, and to operate at equal buck and boost in seven cases, there were twelve cases where they were required to operate at greater boost than buck.

The evidence was plain that the existing voltage standards did not allow the maintaining of voltage at the point of utilization under load conditions unless the voltage at the various generation and transformation points was maintained above normal. The explanation of this was that whereas the existing transformer voltage standards provide for the regulation in the transformer itself by means of taps in the primary, insufficient provision is made for compensating for the line drop in the transmission line and feeders, for, according to the standards, the rated secondary voltage of each transformer is equal to the rated primary voltage of the transformer at the receiving end of the line which the former supplies. Since induction regulators are generally used at only one point in the network, it is often impossible to keep the voltage at all transformation points within the desired limits.

In order to remedy this situation, the Transformer Subcommittee suggested to the Electrical Apparatus Committee as a basis for criticism and discussion, a system of standards where the rated secondary voltage of each sending-end transformer would be five per cent higher than the rated primary voltage of the corresponding receiving-end transformer, in order to allow partially, at least, for the drop in the line. The proposed standards included voltage ratings for generators, synchronous condensers, induction motors, and switching, control, and protective apparatus, in addition to transformer ratings, since the idea of coordinating all of the apparatus on the system had been kept well in view from the beginning.

It was decided to present at the 1927 Winter Convention of the A. I. E. E., a group of papers prepared by the representatives of the operating companies, holding companies, consulting engineers, European engineers and manufacturers.

Proposed System of Voltage Standards

The electrical manufacturers are interested in voltage standardization of apparatus to a perhaps even greater degree than the operators. While the latter are interested in the low prices, rapid shipments, and effective replacement and repair service made possible by standardization, nevertheless it is but natural they should be primarily interested in apparatus which will most perfectly meet their own particular requirements. Thus there is an inherent tendency for individual operating companies to set up standards of their own which might or might not agree with the practise of other operating companies.

The manufacturers, on the other hand, are desirous of a set of standards which will be universal for all customers, in order that their entire output might consist of standard lines of apparatus. The number of types could then be cut to a minimum, development costs reduced, and if proper standards were set up it would be possible to select standard equipment with the assurance that it could be incorporated into a system and form an operative whole.

The proposed standards were drawn up to meet the following five conditions:

a. The new standards must provide apparatus capable of meeting most of the service requirements of a well designed and operated system.

b. The voltages selected must closely resemble those now in use to permit a reasonable degree of interchangeability of new and old apparatus.

c. The changes involved must not necessitate too great an expense in the development of new apparatus.

d. Admittedly, universality of use is an essential end to be sought in all standardization. Usually its complete attainment involves an excessive expenditure, and so is not economically desirable. It should be sought in so far as it can be obtained without burdening the cost of standard apparatus to obtain characteristics which will be used rarely.

e. The new standards must provide apparatus that will meet, in spirit as well as in letter, all requirements as set forth in the standards of the American Institute of Electrical Engineers. The apparatus should not only be capable of meeting the test requirements of the A. I. E. E. Standards, but should readily lend itself to operation within the limits as defined by them. The design of electrical systems contemplating the use of apparatus under conditions more severe than sanctioned by the A. I. E. E. Standards should be discouraged.

The first four of the foregoing principles are self-explanatory but the last will permit of further elaboration. We have to deal here primarily with the test voltage to which apparatus is subjected and its relation to the normal operating voltage of the apparatus. In general, the A. I. E. E. Standards specify a potential test of twice the rated voltage of the apparatus plus 1000 volts in the case of rotating apparatus and transformers (excepting current transformers) and 2¼ times rated voltage plus 2000 volts in the case of switching equipment, bus supports and current transformers. Except where specific mention is made to the contrary apparatus is designed to be operated at substantially its rated voltage, certainly not materially above it. The ratio of test to rated voltage has been selected to introduce a reasonable factor of safety, presumably as the result of theoretical consideration and operating experience. To operate normally above rated voltage is to decrease the recommended factor of safety, and to decrease the factor of safety is to introduce a hazard to life and property not sanctioned by the A. I. E. E. Standards. Or, to put it another way, those who operate apparatus above its rated voltage, operate it with a factor of safety less than the engineers responsible for the A. I. E. E. Standards deem advisable. Can any other conclusion be drawn? It can probably be said, without fear of contradiction, that the practise of encroaching on the universally accepted factors of safety is more prevalent in the electrical arts than in others. Who would contemplate normally operating a steam boiler above its rated pressure? Simply to ask the question is to answer it. The present system of voltage standards has in no small degree contributed to the present undesirable practise. In the case of an average system composed of generators, transformers and motors, rated in accordance with the present voltage standards, either the generators and transformers must be operated above their rated voltages or a subnormal voltage will prevail at the motor when the system is loaded.

In addition to encroaching on the factor of safety relating to test voltage, the operation of generators and transformers for considerable periods of time at pressures exceeding their rated voltage may result in overheating and tends towards reduced life and lower reliability. Such operation may also distort the voltage wave and lead to interference with communication circuits. The operation of oil circuit breakers at pressures materially exceeding their rated voltage may involve marked reduction in their interrupting capacity.

As individual pieces of apparatus are interconnected electrically to form any operative system, it is incumbent upon the designers to determine the maximum voltage at which the system will be normally operated and to be certain that this will not materially exceed the accepted factors of safety for the individual pieces of apparatus of which it is composed. At present the most important rule—if not the only rule—in the A. I. E. E. Standards defining "Rated Circuit Voltage" appears in the Transformer Section (13-119). It has been suggested in the Standards Committee to issue a new general rule, resembling the present one, reading substantially as follows:

Rated Circuit Voltage: For the purpose of fixing a value to be used in designing and testing electrical apparatus, the rated voltage of a circuit (or system) is

defined as the highest rated voltage of the apparatus supplying it. By "circuit voltage" is meant the voltage from line to line as distinguished from line to neutral. This voltage rating applies to all parts of the circuit. The actual operating voltage of the circuit may vary from the rated circuit but should not exceed it.

Such a rule as this and those pertaining to the individual pieces of apparatus would definitely set the rated voltages of apparatus, their test voltages and maximum operating voltage if they are to be operated as parts of a common system.

The present voltage standards, excepting apparatus rated 2300 volts and below, call for apparatus whose voltage ratings are expressed in even multiples of 11; for example, 6600-volt, 13,200-volt, 44,000-volt, etc. excepting that the substation transformers supplying the 2300-volt distribution lines are rated 2300 volts, and the distribution transformers are given the usual triple rating of 2400-2300-2200 volts.

The voltage drops assumed are as follows:

132-kv. line	10	per cent (approx.)
66-kv. line	7½	" " "
13.2-kv. line	5	" " "
2300-volt line	5	" " "
230-115 mains	3	per cent to lamps
and services	6	per cent to motors
Power transformers	5	per cent
Distribution transformers	2	per cent

This diagram shows that with the generator operated at rated voltage the voltage at the 115-volt lamps

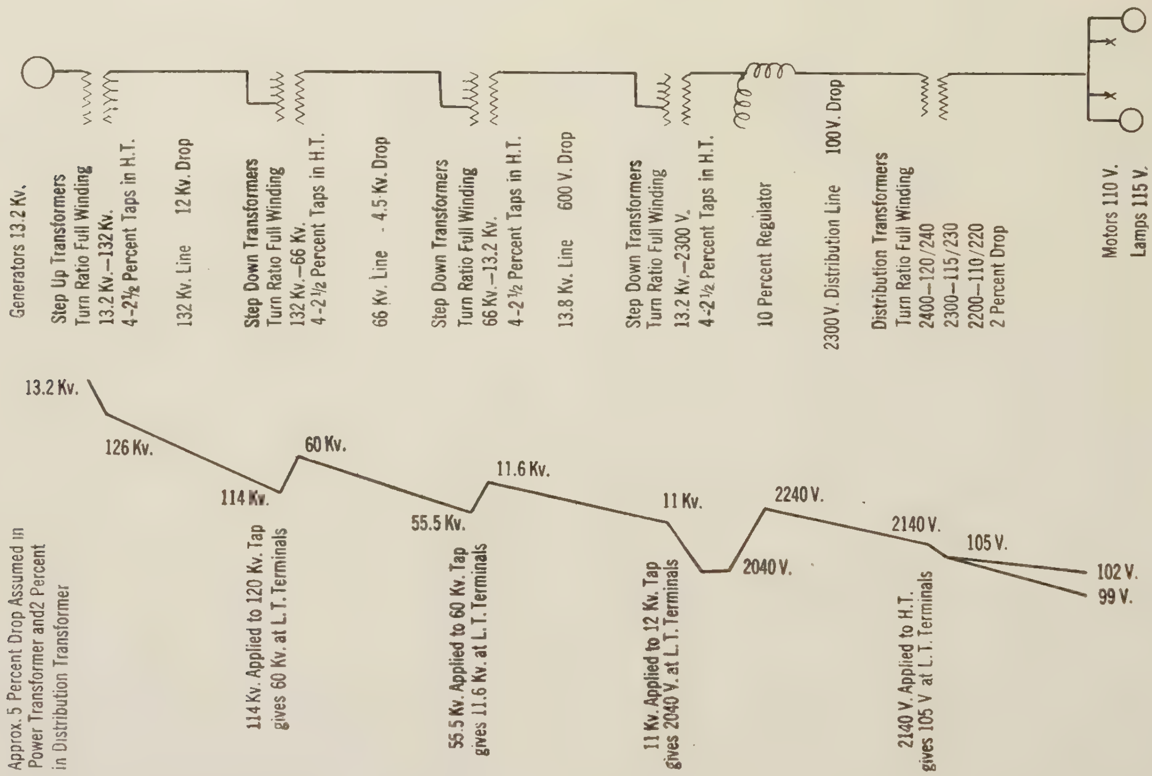

Fig. 1—Transmission and Distribution Connection and Voltage Chart—Old Standard Voltages—Full Load

These voltages apply to motors, transformers (both their primary and secondary windings) and generators, with the exception that in some cases transformers are given a double rating. The second transformer rating simply permits their use at approximately five per cent over-voltage without any change in their voltage ratio. The transformer ratios referred to, of course, are no load or turn ratios. It is usual practise to equip step-down transformers, whose voltage rating exceeds 2300 volts, with four 2½ per cent primary taps below rated voltage. A simple system, employing the present voltage standards, is shown in Fig. 1.

In this elementary but representative system, the voltage ratings of generators, motors, and step-up and step-down transformers are shown as multiples of 11, would be only 102 volts at full load on the system, and the voltage at motors 10 per cent low, even if each transformer is operated on its lowest high-tension tap and a regulator boosting 10 per cent is allowed for. The alternative at present is to over-excite the generating end of the system. It is this that is now so commonly done. If we assume motor and lamp voltages as fixed, it would seem obvious that the principal faults with the present system are that transformer ratios (ratios of primary to secondary) are too high and generator potentials too low.

The new system of standard voltages here proposed contemplates a change in the principle of the present system. An example of the new system is shown in Fig. 2. Here, as in the present system, step-down

transformers (in fact all used at the receiving ends of lines) will be equipped with the equivalent of four 2½ per cent taps in the primary windings below rated voltage. Step-up transformers, for location adjacent to generators, will be equipped with the equivalent of two 2½ per cent taps in the primary windings below rated voltage to provide additional range for compensating for the voltage regulation of the transformers and to avoid over-excitation of generators. A cursory study of the simple principles of voltage standardization as illustrated in Fig. 2 will show that the deficiencies of the present standards have been eliminated. Here, the windings from which power flows have voltage ratings approximately five per cent greater than those at which power is received. It is believed that ample provision has been made in the voltage ratings of apparatus, ratios of transformation, and transformer taps to meet most normal conditions of system design and operation. It will be noted that in Fig. 2, while the generators are operated at rated voltage, and rated voltage is supplied to lamps and motors, there are still remaining taps in reserve in the transformer banks, and only half the boost in the regulator is used. So much for the principle involved in the proposed system—now let us consider the actual voltage values it is proposed to assign to the several voltage classes. These are shown in the accompanying tabulation. They are admittedly a compromise with the present standards. The motor voltages now in use have been retained. In the lower voltage range generator voltages will not be changed; in the upper they will be increased approximately five per cent. Step-down transformers having primaries rated 2300 volts, in which class fall the millions of kv-a. capacity now in use for lighting service, will not be changed. It is proposed to change the ratios of all others so that they will readily conform to the new system. Even here it has been possible to retain ratios (when using tap connections) that will permit paralleling new with old units to a limited extent.

By the definitions previously quoted, the rated system voltage becomes the rated voltage of the generators or secondaries of the transformers supplying the system. It will be noted in the accompanying tabulation that above 4150 volts recommended system voltages are approximately multiples of 11.5 up to and including 69,000 volts; above they are multiples of 11.0. This is a compromise based on a study of existing systems and the cost involved in changing manufacturers' present standard designs. There are so many step-down transformers in the 66,000-volt class and below whose primaries are multiples of 11.0 that it was thought inadvisable to change their voltage ratings, and it was necessary therefore to increase the system voltage ratings and step-up transformer secondary voltages for these classes to multiples of 11.5. The manufacturers' present standard switching equipment (up to and including 73,000 volts) has ample margin in their voltage ratings to permit the proposed increase in system voltage ratings without necessitating changes in their design. Above 69,000 volts, the practise now in general use of standard system voltages that are multiples of 11.0 seems to be satisfactory. While there are theoretical reasons to indicate that a single standard based on voltages which are multiples of

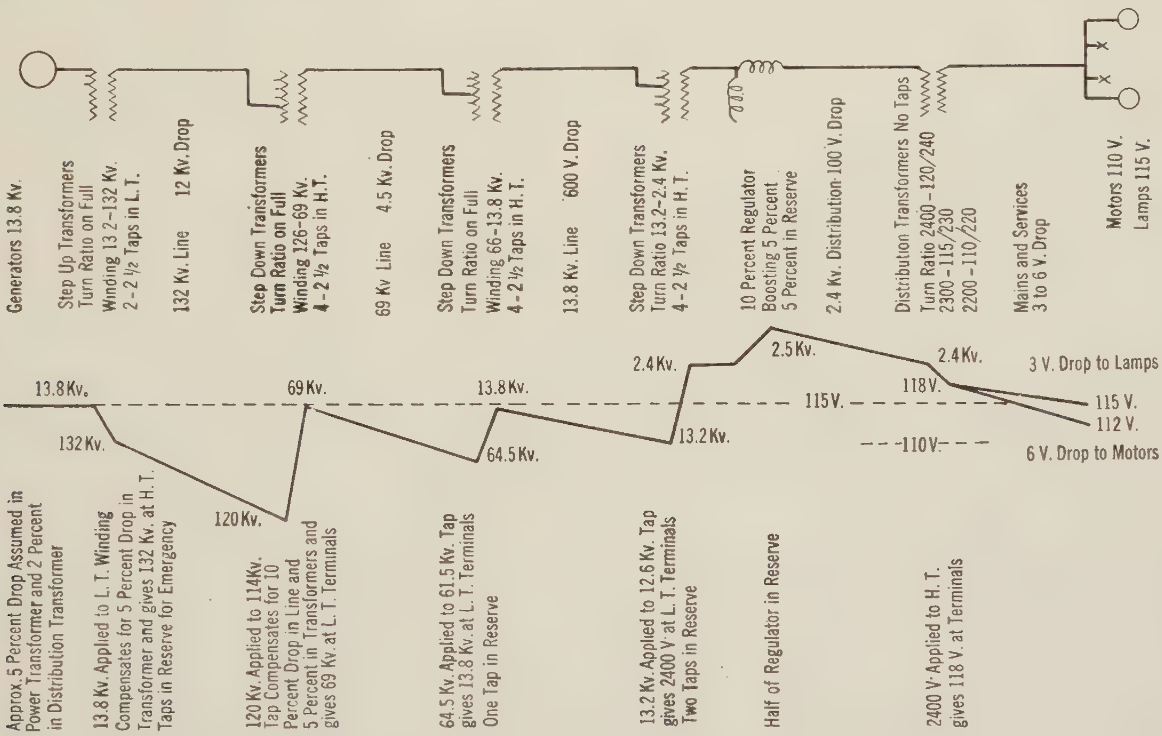

Fig. 2—Transmission and Distribution Connections and Voltage Chart—New Plan—Full Load

11.5 should be established above 69,000 volts, general practise still indicates that this is not as necessary on the high voltages as on the low. The standardization of the higher values would probably necessitate the redesign of most of the present standard apparatus, particularly that of oil circuit breakers, the redesign of which, along with the special tools required for their manufacture, would be an expensive burden on the industry.

The previously cited proposed definition of "Rated Circuit Voltage" provides that the operating voltage should not exceed the rated circuit voltage. This is an extremely difficult, if not impossible, condition to meet in normal operating practise. To fulfill the condition, the generating end of a system must be normally operated below the rated system voltage if provision is to be made to have a margin in the voltage range to overcome abnormal voltage drops between the sources of generation and utilization under emergency conditions, such as the loss of one or more of a parallel group of transmission lines. The A. I. E. E. Standards recognize a not dissimilar condition in the case of motors and transformers (see Standards 5-550, 7-700, 13-500). In the case of motors, the Standards specify that they should operate successfully at rated load at any voltage not more than 10 per cent above or below rated voltage; in that of transformers, that they should operate successfully at rated load when excited on full winding at five per cent above rated voltage. This might be interpreted as a recognition of the fact that under usual conditions it is not practicable always to operate apparatus at rated voltage. It is suggested that this recognition be extended to include other apparatus. To make the range 20 per cent, as in the case of motors, will be costly and probably unnecessary.

It is here suggested that a 10 per cent range be recognized in the case of generators, synchronous condensers, transformers, and apparatus (excluding motors) employed in generating, transmission and distribution systems with the exception of maximum rated apparatus (including under column titled "Apparatus"). It is recommended that these classes of apparatus, which are normally rated, be designed to operate successfully (but not necessarily within the guaranteed limits set for operation at rating) at rated load at any voltage not more than five per cent above or below rated voltage. Of course, apparatus will be operative below 95 per cent of rated voltage, but at reduced capacity. Such a change in the A. I. E. E. Standards will necessitate the manufacture of apparatus capable of operating at rated kv-a. output throughout the voltage range from 95 to 105 per cent of rated voltage. It is

PROPOSED VOLTAGE RATINGS FOR SYSTEMS, GENERATORS, SWITCHING, CONTROL AND PROTECTIVE APPARATUS, TRANSFORMERS, ETC.

Systems	Generators and syn. condensers (see "A")	Induction motors (see "B")	Apparatus (see "C" and "D")	Step-up transformers: Primary (see "E")	Step-up transformers: Secondary (see "E")	Step-down transformers: Primary (see "E")	Step-down transformers: Secondary (see "E")
	120	110					115
	240	220					230
	480	440					460
	600	550					575
2,400	2,400	2,200		2,300/3,980 Y	2,400/4,150 Y	2,300/3,980 Y	2,400/4,150 Y
4,150	4,150	3,800					
6,900	6,900	6,600	7,500	6,600	6,900	6,600	6,900
11,500 (F)	11,500	11,000		11,000	11,500	11,000	11,500
13,800	13,800	13,200	15,000	13,200	13,800	13,200	13,800
23,000			25,000	22,000	23,000	22,000	23,000
34,000			37,000	33,000	34,500	33,000	34,500
46,000			50,000	44,000	46,000	44,000	46,000
69,000			73,000	66,000	69,000	66,000	69,000
88,000			88,000	84,000	88,000	84,000	88,000
110,000			110,000	105,000	110,000	105,000	110,000
132,000			132,000	126,000	132,000	126,000	132,000
154,000			154,000	147,000	154,000	147,000	154,000
220,000			220,000		220,000	210,000	

GENERAL NOTE

Guarantees of efficiency, heating, overload, etc., and over-voltage tests of all apparatus should be based on the rated voltage of the apparatus with the exception of step-down transformers, the over-voltage tests on which should be based on rated secondary voltage; and a primary voltage five per cent greater than rated voltage.

SPECIFIC NOTES

"A"—Generators and synchronous condensers should be designed to deliver rated kv-a. output at rated power factor and frequency throughout a range of five per cent below to five per cent above rated voltage.

"B"—Induction motors should be designed to deliver rated h. p. throughout a range of 10 per cent below to 10 per cent above rated voltage at rated frequency.

"C"—Apparatus, as here used, includes oil circuit breakers, disconnecting switches, current transformers, insulators, bushings and fuses. The voltage ratings of potential transformers should be the same as the recommended system voltage ratings; their secondaries should be rated approximately 115 volts to permit the employment of the now existing even ratios of transformation. Above 73,000 volts, apparatus should be designed to operate successfully at five per cent above rated voltage during emergencies. Up to and including 73,000 volts, apparatus is maximum rated. For maximum rated apparatus the operating voltage of the system on which it is used should not exceed the rated voltage of the apparatus even during emergency operation.

"D"—Lightning arrester voltage standardization recommendations have been omitted pending further study.

"E"—Transformers should be designed to operate during emergencies at five per cent above rated voltage, the over-voltage being obtained by over-excitation and not through the use of taps. They should be equipped with taps as follows:

(a) Step-up transformers should be equipped with the equivalent of two 2½ per cent full capacity taps in the primary windings to provide additional range for compensating for the voltage regulation of the transformers and to avoid over-excitation of generators.

(b) Step-down transformers should be equipped with the equivalent of four 2½ per cent full capacity taps in the primary windings to provide additional range for compensating for line voltage drop.

"F"—When possible, 11,500-volt systems should be discouraged in favor of 13,800-volt ones.

expected that the five per cent range above rated voltage will be reserved to meet emergency conditions. In other words, systems will be designed to operate normally at a voltage not to exceed their rated voltage. High potential tests will be based, as at present, on the rated voltage of apparatus, or, more accurately, on the "rated circuit voltage" of the system of which the apparatus forms a part. Maximum rated apparatus as given in the attached tabulation, *i. e.*, circuit breakers, disconnecting switches, etc., already contains the necessary tolerances in their maximum ratings and should not be used above such ratings.

It is expected that the rated voltages proposed here for step-up and step-down transformers, the essential feature of the plan, will make it possible to standardize apparatus so that it will meet most existing operating conditions without the necessity, which now prevails, of exceeding the established rating limits of the apparatus. Operators, under most conditions, will find it possible, when employing the proposed standard apparatus, to deliver rated voltage to apparatus at all points of their systems without exceeding the rated voltages of their systems.

The accompanying tabulation, with the foot notes included with it, presents a brief summary of the proposed new system of voltage standards. A few further explanatory remarks might prove helpful in understanding it. The first column presents a list of the proposed "Rated Circuit Voltages." These set the maximum normal operating voltages of systems. It is proposed to permit operation at five per cent above these values but, as just mentioned, it is suggested that this margin be reserved for emergency operation. The second and third columns hardly need further explanation. In the fourth column the heading "Apparatus" is employed in a restricted sense, in the absence of a better term, to include oil circuit breakers, disconnecting switches, current transformers, insulators, bushings and fuses. Years ago manufacturers standardized "apparatus" voltages up to and including 73,000 volts on the basis of maximum ratings, which is to say, without a five per cent over-voltage margin. The values were chosen after a study of the operating voltages of the then existing systems. The investigation revealed a conspicuous absence of voltage standardization in the range considered and maximum voltage values therefore were chosen somewhat above the more common voltages in use to include the numerous groups operating above the average voltages. The voltages of systems operating above 73,000 volts were fairly well standardized as multiples of 11.0, and so for these groups manufacturers standardized apparatus voltages as multiples of 11.0, but included a five per cent over-voltage operating margin for emergency operation. Higher values and greater over-voltage margins were considered but rejected because there seemed to be no logical reason or necessity to justify burdening users with the greater expense of higher-voltage apparatus, particularly as all high-voltage apparatus is inherently expensive. Such in the explanation of why apparatus up to 73,000 volts is maximum rated and above nominal rated. The fifth and sixth columns, headed "step-up transformers," include the voltage ratings of transformers used at generating stations, where the potential drop between the generators and transformers is nil. The seventh and eighth columns refer to transformers used at the receiving ends of lines. Most of these will be step-down units. There are a few instances where step-up transformers must be installed at the ends of transmission lines. The voltages and taps of these should be selected from the seventh and eighth columns. Of course, the transformer voltages given in the tabulation are no load or turn-ratio voltages.

Economic Advantages of Voltage Standardization

From these it is estimated that there is roughly two billion dollars worth of electrical apparatus now in operation in the United States, of which somewhere between 20 per cent and 50 per cent is special, depending on the particular type, with the exception of lamps which are only about eight per cent special. If all the specials had been eliminated, the industry would have experienced, from two causes, a worth while reduction in this two billion dollars, the effects of which are roughly evaluable:

1. Standard apparatus would not have had to bear part of the development cost of the specials,

2. The increased sale of standards to take the place of the specials would have caused a further reduction in their price in accordance with the law of quantity production.

Estimates by various methods indicate that the effect of the use of special apparatus has been to increase the total investment in electrical apparatus by from 100 to 200 millions or from five to ten per cent of the total.

The proposed standardization of system voltages and apparatus voltages fitting in with the already standard utilization voltages should have a marked effect in the reduction of these extra investments in the future. This standardization should also make available considerable economies in the industry through facilitating interconnection and reducing the extra investments required for interconnection.

Conclusions

1. The present system of voltage standards is not suited to operating conditions since insufficient allowance is made for voltage drop in lines and transformers.

2. The extensive use of special apparatus for maintaining proper voltage at the load, supports this contention.

3. The use of special apparatus is undesirable since it raises costs, delays deliveries, reduces interchangeability of apparatus from point to point of a system or connected systems, impedes the policy of system inter-

connection recommended by the National Electrical Light Association, and reduces the efficiency of renewal and repair part service.

4. A new system of voltage standards is proposed whereby all apparatus on the system will be rated to conform to the following transformer ratings: Up to and including 69,000 volts, the primaries of transformers will be rated on the basis of multiples of 11, (except the 2300-volt class), and the secondaries on the basis of multiples of 11.5; above that voltage the primaries will be rated on the basis of multiples of 10.5, and the secondaries on the basis of 11. This will allow for approximately five per cent greater voltage drop in lines and transformers than is now possible without reducing the voltage at the load. All other apparatus on the system will be rated in accordance with these voltages.

5. It is expected that the adoption of these proposed standards would eliminate the use of apparatus which is special with respect to voltage, and would therefore help remedy a situation which has cost the public from \$100,000,000 to \$200,000,000.

6. It is believed that the plan set forth here will fulfill the five conditions set forth in earlier paragraphs, and furnish an escape from the present embarrassing dilemma and it is hoped that those interested in this question of a-c. voltage standards will accept and consider this proposal in the spirit in which it is offered, namely, simply as a basis of discussion, as a seriously and comprehensively thought out plan of voltage standards for all apparatus employed in transmission systems. It will fully serve its purpose should it lead ultimately to a rational set of standards which can be employed with a reasonable degree of success in new systems and throughout an appreciable part of existing ones.

Application of Mercury Arc Power Rectifiers

BY C. A. BUTCHER[1]

Member, A. I. E. E.

Synopsis:—*Interest in the mercury arc rectifier has grown considerably in America in the last few months. The apparent advantages of the rectifier in higher capacities and for higher voltages have attracted the attention of operators. It should therefore be of interest to present some information on the characteristics of rectifiers, and some comparisons with rotating converters as to operation, cost, floor space, weight, etc.*

* * * * *

Characteristics of the Modern Large Power Rectifier Compared with Commutating Machines

Efficiency. From Figs. 1 and 2 it will be noted that for voltages below 500, the efficiency of the rectifier installation is less than that of the synchronous converters except at light loads, while at higher voltages, for example at 1500, the rectifier shows a decided advantage over the synchronous converter in this respect.

Regulation. An isolated rectifier unit will have, in general, a voltage regulation of from 5 to 10 per cent, depending on transformer design and the scheme of connections employed. It will be appreciated that since the internal voltage drop of the rectifier tank is constant, the d-c. voltage regulation at the terminals depends on the transformer inductance and the characteristics of the a-c. supply.

In installations where parallel operation with synchronous converters or motor-generators is required, interphase transformers and other auxiliary equipment may be employed for producing a satisfactory voltage characteristic. In general, parallel operation with shunt wound machines will be satisfactory without the employment of auxiliary devices.

Rating. Either one of two conditions, *viz.*, temperature or commutation, will limit the output capacity of commutating machinery. Standard synchronous converters for use in railway service are guaranteed under rules of the A. I. E. E. to carry 150 per cent load for two hours after reaching constant temperature at

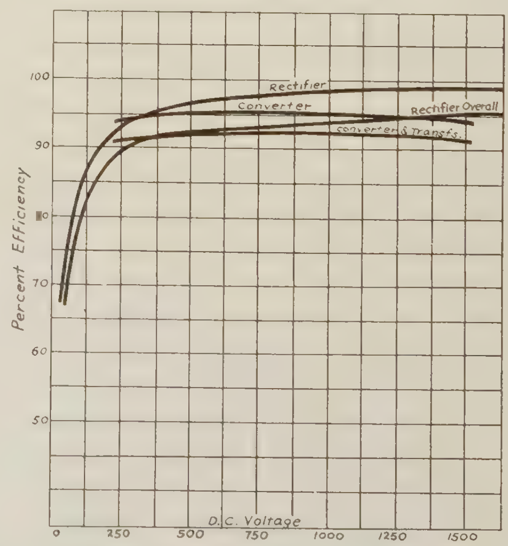

Fig. 1—Comparative Full Load Efficiencies of Rectifier and 60-Cycle Converter

full load without exceeding a temperature rise of 55 deg. cent. on insulated parts and 60 deg. cent. on current-collecting parts. Synchronous converters for light and power service, under ruling of the A. I. E. E., are

1. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Presented at the Regional Meeting of District No. 7 of the A. I. E. E., Kansas City, Mo., March 17-18, 1927.

given a continuous rating based on 50 deg. cent. rise for insulated parts and 60 deg. cent. rise for current-collecting parts. As yet the A. I. E. E. has not made any ruling as to rating for mercury power rectifiers. In the absence of such rating, comparison can be made only by considering the performance to be expected in a given service.

Except that undue maintenance of the current-collecting parts would be required and much shorter than normal life of insulation would result, modern railway converters might be operated continuously at 50 per cent above nominal rating. In giving a 50 per cent overload rating to railway converters, it is expected that operation at such loads will be infrequent. The system load factor of metropolitan railways averages approximately 40 per cent and substations are so operated that the plant factor, which is a measure of all day conversion efficiency, is from 60 to 90 per cent with an average of probably 75 per cent. With increase in load, additional machines are added so that equipment seldom operates at overloads. In general, operators consider the overload rating as reserve capacity to meet unusual demands and contingencies of service.

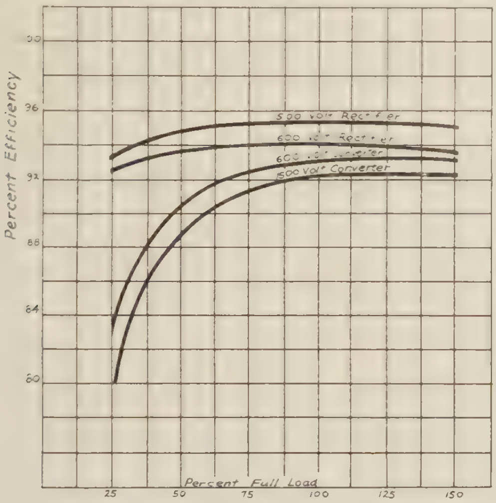

FIG. 2—COMPARATIVE OVER-ALL EFFICIENCIES OF RECTIFIER AND 60-CYCLE CONVERTER

In interurban or light duty railway service, the load factor, as an average, is approximately 25 per cent. The plant factor, with careful manual control of machines which includes shutting down over periods of light load or no-load, and in cases of automatic operation, may be as high as 60 per cent. On one particular property with which the author is familiar, the plant factor on seven substations—six 300-kw. stations and one 500-kw. station—varies from 36.7 per cent to 87.4 per cent. These stations are all automatically operated. Two of the stations supplying urban as well as interurban service on one-hour headway have plant factors of 36.7 and 41.0 per cent.

The demand on these stations is characterized by peaks of only a few moments' duration, equal to 300 per cent of substation rating, and for periods over daily peak loads; the stations supplying both urban and interurban service are required to carry from 25 to 50 per cent overload for periods of one hour or more. Since single-unit stations are employed, the overload capacity of adjacent stations has met demands satisfactorily when one station has been out of service.

Street railway service is in greatest demand over two definite periods totalling four hours each day except Saturday and Sunday. The periods are known as the morning and evening peaks, each lasting overall about two hours when people are going to and returning from their daily employment. It is in this period and at times of exceptional seasonal loads that service must be had at almost any cost, and the railway operator knows that on his success in handling his peaks largely depends the reputation of his company with the public. It is this period of daily peak load demand which has set the period for overload rating on railway substation equipment.

In purely interurban service, there will be ordinarily little or no demand for two-hour overload capacity unless freight service is operated on a rather extensive scale. Machines are applied to such service almost entirely on their ability to commutate momentarily heavy loads.

While it is true that modern synchronous converters for railway service could be given an appreciably higher rating on a continuous basis, the experience and practise in the operation of our electric railways, having established the basis for the two-hour rating, will probably make it necessary to compare the rectifier for electric railway service on the same basis.

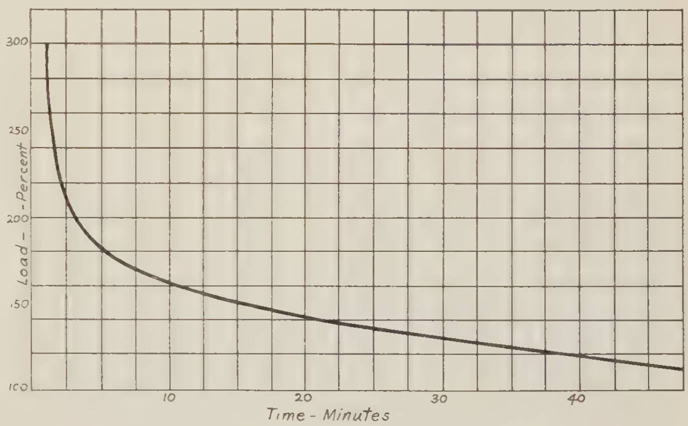

FIG. 3—OVERLOAD CAPACITY OF RECTIFIER

(Note that this is Fig. 20 of the paper, *The Rectification of Alternating Currents with Steel Enclosed Mercury Arc Power Rectifiers and Their Auxiliary Devices*, by O. K. Marti, delivered at the Regional Meeting of District No. 1 of the A. I. E. E., Niagara Falls, N. Y., May 26-28, 1926).

European manufacturers ordinarily have not given two-hour overload guarantees on rectifiers; however, it will be noted from the Fig. 3 that the rectifier is capable of carrying high momentary loads. This characteristic makes it a desirable unit for service in interurban substations, particularly on properties operating multiple unit trains. Momentary ratings rather

than nominal ratings will be the basis of comparison in such cases.

Considering light and power service, the rectifier, as it has been rated by European manufacturers, may be applied on the same basis as converters having a continuous rating.

Power Factor. The power factor of the polyphase rectifier, on the average, is between 93 and 96 per cent, dropping gradually at loads above ¾ and more abruptly below ¼ load to about 80 per cent at 10 per cent load. The power factor will be influenced to some extent by the characteristics of the a-c. supply system. This power factor is not subject to adjustment as in the case of the synchronous converter or synchronous motor. The power factor is superior, however, to the average industrial load and would therefore not appear as a disadvantage on the average power system except where power contracts are drawn with a clause which offers bonus to the consumer for high average power factor.

A typical power contract provides multiplier constants based on effective monthly power factor as follows. The average power factor is that taken as the cosine of the angle, the tangent of which is equal to the ratio of metered reactive kilovolt-ampere hours to kilowatt-hours.

Effective Monthly Power Factor	Constant
1.00	0.951
0.95	0.965
0.90	0.981
0.85	1.000
0.80	1.023
0.75	1.050

Data available on a typical interurban property show an average power factor of 0.9703 per cent for synchronous converters which gives a multiplier constant of 0.9589. Using a power factor of 93 for rectifiers, the constant would be 0.971. In his paper, "The Rectification of Alternating Currents with Steel Enclosed Mercury Arc Power Rectifiers and Their Auxiliary Devices," read at the Niagara Falls Meeting of A. I. E. E., May 26-28, 1926, Mr. O. K. Marti gives the average power factor as between 90 and 95 per cent. In this particular case, the difference represented is equivalent to a saving of approximately $165.00 per station per year for the converter stations. In addition, there is a kilovolt-ampere demand charge of $30 based on a 15-minute period. At the lower power factor, it is obvious that for 600-volt equipment, the efficiencies at rated load being so nearly the same, the rectifier is at a disadvantage when the demand charge is on a kilovolt-ampere rather than a kilowatt basis.

Regeneration. Since the valve action of the rectifier allows passage of current in only one direction, it is not applicable for regeneration. While the synchronous converter may be operated inverted, it has not been generally employed in railway electrification in which regeneration is used as an effective and economical means of braking heavy trains. The characteristics of the motor-generator being more suitable for this application, most of which have been made at voltages 1500 to 3000, have led to the selection of the motor-generator for such duty.

Ventilation and Cooling. Ventilation of substations equipped with rotating electrical equipment is in some cases a very serious problem. This is especially true where installations of large capacity are crowded into small spaces in expensive property situated in the congested centers of metropolitan areas. Elaborate and therefore costly schemes of forced ventilation and air cleaning are resorted to, for proper dissipation of heat.

For directing cooling air and to mitigate the nuisance of objectionable noises, converters are sometimes either partially or totally enclosed at considerable expense.

Since the rectifier tank is water cooled and operates silently, its installation in such locations is an advantage very much in its favor. In combination with water cooled transformers, ventilation is not a problem. Noise is only that resulting from transformer hum and the operation of the air pumps.

In many installations of small capacity such as in electric traction, suitable space is available and inexpensive means of natural ventilation provide adequate cooling for rotating equipment.

Since water must be available for cooling the rectifier tank, it may be a problem to secure this water where installations are made in country locations where tap water is not available. The development of a well and the required pumping system may constitute a problem. In cases where water is not readily available, a closed system for recirculation may be the best solution.

It is obvious that in the colder climates, precautions must be taken to prevent freezing.

Maintenance. Much of the cost of maintenance of modern high speed commutating machines is incident to upkeep of the current-collecting parts. As to what will constitute the principal item of maintenance in rectifier stations is not definitely known, but it is quite certain that it will be that incidental to the maintaining of the very high vacuum required. It will be only after a number of years that any conclusions can be drawn as to the comparative maintenance of synchronous converters in the same service.

Figures available from a large number of railway properties in the United States operating automatic substations, disclose that for inspection and general maintenance the cost per kilowatt per year varies from $0.21 to $2.95 with the average at $1.12, which average is equivalent to approximately $720.00 per substation per year. Of this latter amount, approximately 85 per cent is estimated to be labor. Assuming that one man, at a rate of $200.00 per month, can look after five small automatic substations, the inspection cost per substation is equal to $600.00. With the present stage of development, the inspection time required for an automatically controlled rectifier substation will be probably, at least for some time, more than required for

an automatically controlled synchronous converter substation. It is also doubtful if the maintenance of the rectifier and its auxiliaries will be any less than the small item required to cover actual labor and material for repairs on the synchronous converter and its coordinated equipment.

Some of the maintenance items incident to the operation of the rectifier are the cleaning of the inside of the tank, the purification of the mercury, the removal of deposits from the areas in contact with the cooling water, an occasional painting as protection against rust, adjustment of the pumps, etc. While such overhauling is required only after long intervals of time, it probably compares with the major repairs to synchronous converter substations such as grinding of commutator and rings, renewing brushes, changing oil in the bearings, painting, etc.

The actual time required for overhauling may be longer in the case of the rectifier than with the synchronous converters since complete reforming such as is required for the initial starting of the rectifier plant may be required if it is necessary to keep the tank open for longer than a few hours. This consists of operation at reduced voltages for the generation of heat in the metal parts to drive off occluded gases from the metal parts. The operation may be hastened by first applying heat externally, either electrically or by circulating hot water to drive off any moisture. The process usually requires between two and three days under favorable conditions. In general, the work on the inside of the tank would not require more than a few hours in which case complete reforming is not required and a period of only five or six hours would be required for the complete restoration of vacuum.

Cost Comparisons

Cost comparison of rectifier and synchronous-converter automatic substations at 600 volts d-c. for service of low load factor is as follows: A 500-kw. standard railway synchronous-converter equipment which is given a two-hour overload rating is compared with a 600-kw. mercury arc power rectifier rated on a continuous basis but capable of carrying momentary loads equal to that of the synchronous converter. This is a case which is typical of the average American interurban single-unit substation.

500-KW. AUTOMATIC SYNCHRONOUS CONVERTER SUBSTATION

Cost of equipment installed (automatic)	$25000.00
Cost of building and foundations	5000.00
Total investment except real estate	$30000.00
Conversion loss at full load, kw.	37.6
Annual conversion losses, kw-hr.	
Machine at average 1/3 load 12 hr. per day	110,000
Machine at average 2/3 load 4 hr. per day	44000
Machine at rest 8 hr. per day	
Total kw-hrs.	154,000
Annual Costs	
Equipment at 15 per cent	$3750.00
Buildings at 10 per cent	500.00
Operation and maintenance	750.00
Energy charge for conversion losses at $0.0125 per kw-hr.	1925.00
Total annual conversion cost	$6925.00

600-KW. AUTOMATIC MERCURY ARC POWER RECTIFIER SUBSTATION

Cost of rectifier, transformer and switching installed	$24000.00
Cost of well and pump for cooling water	1800.00
Cost of building, foundations and well house	5500.00
Total investment except real estate	$31300.00
Conversion loss at full load, kw.	38
Annual conversion losses, kw-hr.	
Rectifier at average 167-kw. load 12 hr. per day	56940
Rectifier at average 333-kw. load 4 hr. per day	32120
Rectifier at rest 8 hr. per day	
Total.....kw-hrs.	89060
Annual Costs	
Equipment at 15 per cent including well	$3870.00
Building at 10 per cent	550.00
Operation and maintenance	750.00
Energy charge to conversion losses at $0.0125 per kw-hr.	1113.25
Energy charge for pumping water and heating during cold freezing weather	110.00
Total annual conversion cost	$6393.25

It is obvious that lighter load factor will increase the advantage of the rectifier in the above comparison while increase in load factor will make the two practically equivalent. At the higher voltages there would be still lower losses to the credit of the rectifier. It will be obvious from inspection of the comparative efficiency curves that for mining and industrial railways at 250

Cost Comparison of Synchronous Converter and Rectifier Substations Each Rated at 750 Kw. For Two Hours

500-KW. AUTOMATIC SYNCHRONOUS CONVERTER SUBSTATION

Cost of equipment installed	$25000.00
Cost of building and foundations	5000.00
Total investment except real estate	$30000.00
Conversion loss at full load, kw.	37.6
Annual conversion losses, kw-hr.	
Machine at 375 kw. 24 hr. per day	270,000
Annual Costs	
Equipment at 15 per cent	$3750.00
Buildings at 10 per cent	500.00
Operation and maintenance	800.00
Energy charge for conversion loss at $0.0125 per kw-hr.	3375.00
Total annual conversion cost	$8425.00

500-KW. (750-KW. FOR 2 HR.) MERCURY ARC POWER RECTIFIER SUBSTATION

Cost of equipment installed	$29000.00
Cost of building and foundations	5000.00
Total investment except real estate	$34000.00
Conversion loss at 500-kw. load, kw	32
Annual conversion losses, kw-hr.	
Rectifier at 375 kw., 24 hr. per day	228000
Annual Costs	
Equipment at 15 per cent	$4350.00
Building at 10 per cent	500.00
Operation and maintenance	800.00
Energy charge for conversion losses at $0.0125 per kw-hr	2850.00
Cost of cooling water	180.00
Total annual conversion cost	$8680.00

volts, there would be no economy in the use of rectifiers.

Weight and Space Requirements. By comparison with 60-cycle, 600-volt railway converters and on a comparable basis of rating; *viz.*, 150 per cent load for two hours after reaching constant temperature at full load,

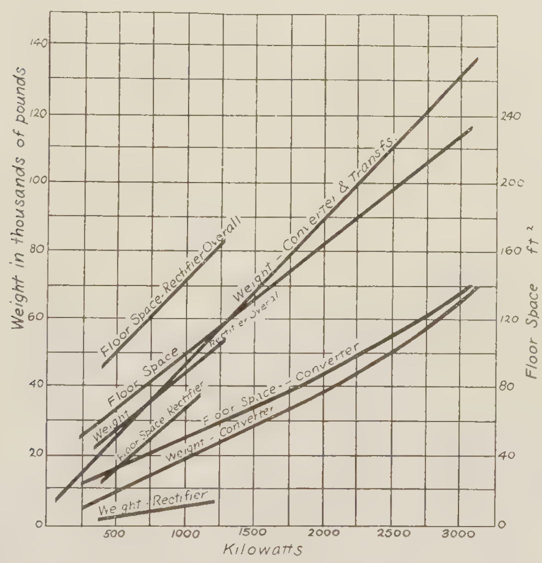

Fig. 4—Curves Showing Floor Space and Weight of Two Converters in Comparison with Mercury Arc Rectifier (600-Volt)

the equipment for a rectifier station weighs considerably more and requires much greater floor space than an equivalent converter outfit. This is particularly true of the larger ratings, the two being more nearly comparable in the smaller ratings.

The weight and space requirements are in favor of the synchronous converter at voltages below 600 while the situation may be reversed at the higher voltages since the weight per kilowatt of the rectifier tank at the higher voltage is very much less than rectifiers at the lower voltages.

Without considerably more experience in the operation of rectifier substations in 600-volt electric railway service, it cannot be said with justification that it will

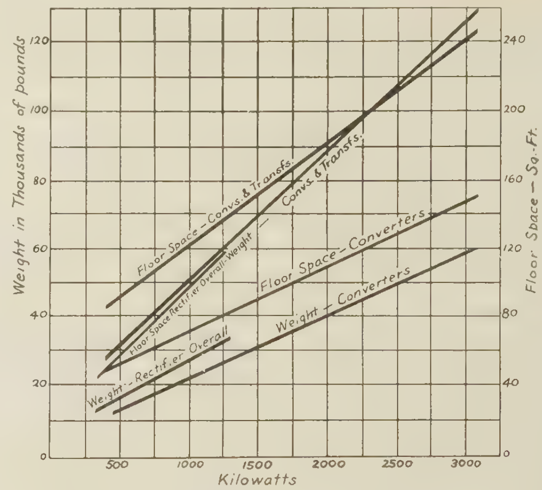

Fig. 5—Curves Showing Floor Space and Weight of Two Converters in Comparison with Mercury Arc Rectifier (1500-Volt)

be either more or less satisfactory than the synchronous converter. The most promising field, at least for the present, is in the electrification of railways at higher d-c. voltages.

RUBBER GOODS MADE BY NEW PROCESS

How rubber articles are produced electrically by a method like metal plating was described recently at a meeting of the Detroit section of the Society of Automotive Engineers by the inventor of the process, Dr. S. E. Sheppard, of the Eastman Kodak Co. The commercial advantages of the process and the superiority of the products made by it were told at the same meeting by J. W. Schade, director of laboratories of the B. F. Goodrich Co.

The process consists of passing an electric current through a mixture of rubber latex, or uncoagulated milk of the rubber tree, with water, sulphur, fillers, accelerators, softeners and other materials, according to the various requirements of the articles to be produced. The particles of rubber and other materials become charged electrically and are deposited together on molds of the desired shape, just as copper or nickel are deposited on metal articles when plating. When the mixture of rubber and other ingredients is electrodeposited, the composition remains substantially unchanged during the coating and the resulting rubber is of the same composition as the solution. This is essential to the success of the process, because the rubber compound produced must be similar to rubber produced by the mechanical masceration and compounding method.

Rubber is much easier to deposit than nickel, for with the same amount of electric current a coating 1400 times as thick as nickel-plating can be deposited.

Reduction of Armature Copper Losses

The Inverted Turn Transposition for the Reduction of Losses Due to Non-uniform Current Distribution in the Armature Conductors of Large A-C. Machines

BY IVAN H. SUMMERS*

Associate, A. I. E. E.

Synopsis.—*A new method of reduction of armature copper losses is described, which consists in the inversion of the conductors of a multi-turn barrel type coil at one or more places in the end portions of the coil. Previous writers have described methods of transposing the conductors in the slot and of carrying insulated strands through successive positions in successive coils, but the new method now described presents distinct points of difference in theory and in construction from any of these earlier methods. The theory of the new form of transposition is briefly described, complete formulas are presented for the most useful cases, and illustrations of its use are given.*

* * * * *

It is the aim of this paper to present a method for the reduction of extra losses and heating in armature conductors of large a-c. machines due to non-uniform current distribution. The scope of the paper is limited to finitely laminated conductors with the laminations insulated throughout all the turns in a coil. It is further limited to coils wound either with no special twist or inversion at any point, or with one or more of the turns or half-turns inverted as illustrated in the various accompanying diagrams. With the aid of the formulas and tables the calculation of the extra copper losses becomes a simple matter for simple untransposed coils, and the gain to be derived from transposition can be determined by selecting the proper factor from the tables. It is found that in most cases it is a simple matter to select a transposed winding for a large machine so that the extra losses will be reduced to a negligible value and the transposition may be accomplished at very slight additional expense.

A considerable literature on the subject of reduction of eddy-current losses in the armature copper has accumulated, as is evident from an inspection of the bibliography. Nevertheless, the type of transposition here described, which consists in inverting the conductors of a multi-turn coil at one or more points in the end connections during the process of winding, is believed to be entirely new. European writers have chiefly described means of transposing the strands of a bar winding within the slot, thus enabling both ends of the bar to be solidly connected to adjacent bars. American writers have described the reduction of losses secured by the inversions occurring at both ends of the standard barrel type coil, as shown in Fig. 1, and have also described the further means of reducing the losses, which consists in carrying the strands through the several coils of a phase belt by special insulated connections. The earlier papers by Mr. W. V. Lyon and by Mr. H. W. Taylor (see bibliography) have been of great assistance in furnishing foundations for the present paper.

The new method now described has some distinct advantages in construction over other methods, as it enables solidly connected machine wound coils of identical character to be made practically free from circulating current losses, whatever the number of turns per coil. By making the transpositions in the ends of the coil, space for them is obtained without sacrifice of slot room, and by properly locating them with reference to the already present inversions at the ends of the coils, almost complete avoidance of residual voltages can be secured. Diagrammatic illustrations of the various types of transpositions in the ends here considered are shown in Figs. 2 to 7 inclusive, and a reproduction of an actual coil similar to Fig. 6 is shown in Fig. 9.

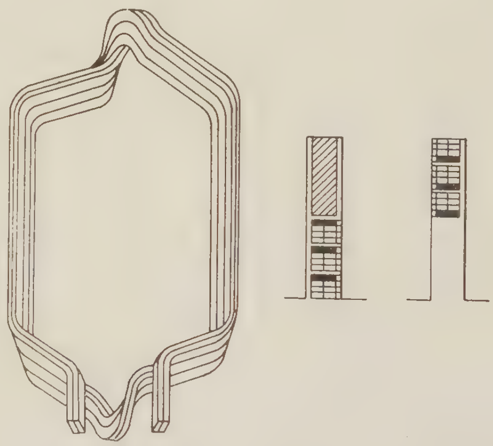

FIG. 1—STANDARD BARREL TYPE COIL

Showing successive positions in slot of a single strand—Type I, Table I

Consider a solid rectangular conductor placed in a rectangular slot in an iron body. It is clear that the reactance of a path at the bottom of the conductor is more than that of any other path in the conductor because the bottom path is enclosed by more flux. Furthermore, a path at the extreme top of the conductor

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

is reactanceless with regard to the rest of the conductor, and in this respect has resistance only. Thus a larger current will flow at the top than at the bottom. Additional losses will ensue and the temperature will be higher than if uniform current distribution were maintained. This non-uniform current can be thought of as a uniform current with an eddy current superimposed on it so as to increase the total current at the top and decrease it at the bottom. When the term eddy current is used hereafter in this paper, it means this hypothetical superimposed current. The formulas for extra loss factor give the ratio between the loss caused by this eddy current and the loss caused by the uniform current.

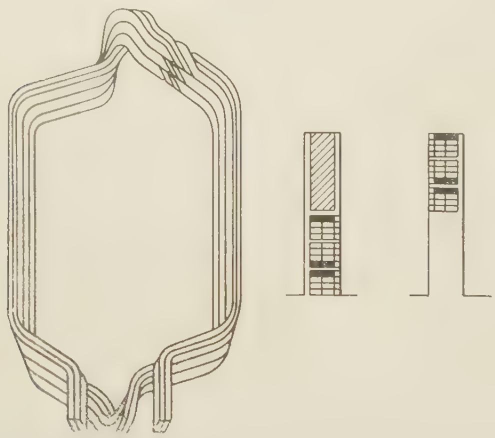

FIG. 2—BARREL TYPE COIL WITH ODD NUMBER OF TURNS
All inverted at the end opposite connections—Type II, Table I

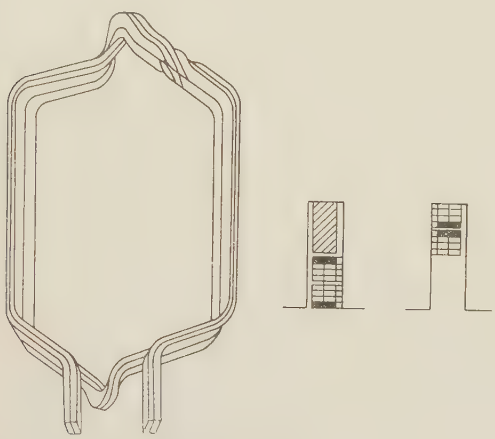

FIG. 3—BARREL TYPE COIL WITH EVEN NUMBER OF TURNS
All inverted at the end of connections—Type II, Table I

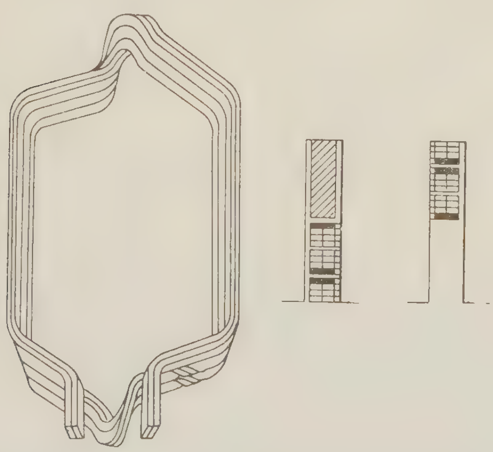

FIG. 4—BARREL TYPE COIL WITH ODD NUMBER OF TURNS
All inverted at the connection end—Type III, Table I

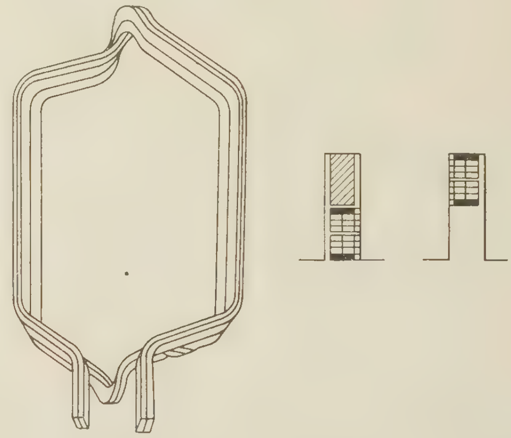

FIG. 5—BARREL TYPE COIL WITH EVEN NUMBER OF TURNS
All inverted at the connection end—Type III, Table I

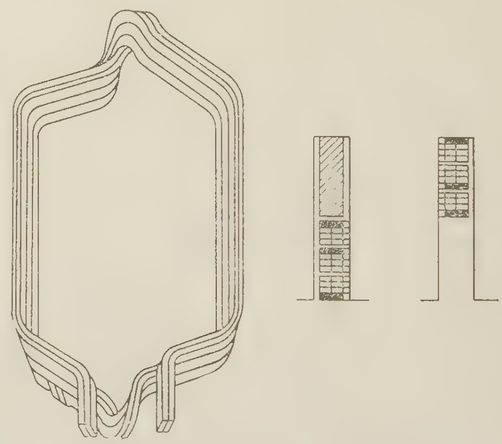

FIG. 6—BARREL TYPE COIL WITH LAST TURN ONLY INVERTED AT CONNECTION END—TYPE IV, TABLE I

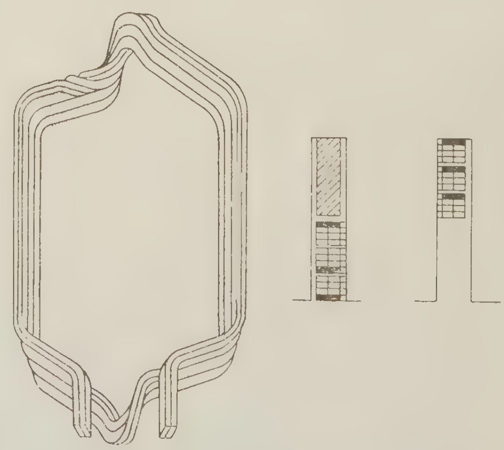

FIG. 7—BARREL TYPE COIL WITH FIRST HALF TURN ONLY INVERTED AT END OPPOSITE CONNECTIONS—TYPE V, TABLE I

If the conductor be laminated, conditions will be improved because the paths will be longer and the eddy currents reduced. Thus an elementary method of reducing the extra losses is simply to laminate the conductor. In addition, this makes the coil more flexible and easier to handle. For this reason most coils in large machines are laminated. Mere lamination, however, is not sufficient to keep the extra losses down to a negligible amount and for this reason various other schemes have been proposed.

The new method now proposed is to invert the laminations at various points in the coil by making a 180-deg. twist in the conductor. This can be arranged usually so that the voltage induced in the whole length of the strands by the leakage flux is more nearly uniform than it would be if there were no inversion. Some of the convenient ways of employing the inversion are illustrated in the accompanying diagrams. They are discussed later and formulas are given to calculate the extra losses which the coils will have.

In order to investigate mathematically the problem of inversion of the turns, certain simplifying assumptions are convenient as in all engineering problems. These are briefly indicated below:

1. Only the horizontal components of flux and magnetizing force are considered. Actually there are additional losses due to the vertical components but these have been found to be small in most practical cases. Horizontal is taken here to mean parallel to the bottom of the slot.

2. The vertical component of current is neglected. The current is always considered to flow straight into or out of the plane of the paper, except, of course, at the soldered joints at the ends of the coils.

3. The iron sides and the bottom of the slot are considered to have infinite permeability and no losses, as far as this problem is concerned.

4. The resistivity of the conductors is supposed to be constant and invariable over the depth of the slot.

5. The voltage induced by the leakage flux in the end connections is the same for each strand.

These assumptions are the same as the ones made by most writers on the subject. From the fundamental laws of electromagnetic theory and these assumptions, the differential equations of the problem can be derived. From these differential equations and their solutions, a general rule for finding the loss in any conductor or combination of conductors can be derived.

Circulating Current Loss

For a neat statement of the problem and a derivation of rules for finding the loss in infinitely laminated coils (hereafter called circulating current loss) see the paper by W. V. Lyon in the May 1921 issue of the Journal. The rule derived therein may be briefly restated as follows:

Form a quantity I_0 for each conductor which is right side up in the slot by taking

$$I_0 = I_b,$$

where I_b is the vectorial summation of all the currents in the slot below the conductor in question. For each conductor which is the other side up, take

$$I_0 = -(I_b + I_1),$$

where I_1 is the current in the conductor considered. It makes no difference which side up is called right side up. The I_0 used is the average for all the conductors which are in series, and which have strands continuously insulated throughout. Let I_2 be all the current in the bottom coil side of another coil which may be in the slot below the conductors in question and substitute the known value of I_2 in terms of I_1 and solve for $|I_0/I_1|$ and $\cos\alpha$, where $|I_0/I_1|$ is the numerical value of the ratio and α is the angle between I_0 and I_1. Substitute these values in the relation

$$L = \left|\frac{I_0}{I_1}\right|^2 + \left|\frac{I_0}{I_1}\right| \cos\alpha. \tag{1}$$

Then the heat loss in the coil will be determined from the relation

$$K = M + LN, \tag{2}$$

where M and N are certain complex hyperbolic quantities[1] and K is the ratio of the total heat loss in the coil to the loss that would exist if the uniform component of the current existed alone.

These quantities are discussed in Appendix B where it is shown that if the current has a distribution which is not widely different from uniform, the extra loss factor due to the eddy currents may be approximated by

$$k = (4 + 15\,L)\,D, \tag{3}$$

where D is a quantity depending on the dimensions of the slot and the coil. It is

$$D = 0.075\left[\frac{f}{60/\text{sec}}\right]^2\left[\frac{r\,b\,n^2\,(d/\text{in})^2}{m^2}\right]^2 \tag{4}$$

for a two-coil side per slot winding. Also

$$D = 1.19\left[\frac{f}{60/\text{sec}}\right]^2\left[\frac{r\,b\,n^2\,(d/\text{in})^2}{m^2}\right]^2 \tag{5}$$

for a one-coil side per slot winding, and

$$D = 1.19\left[\frac{f}{60/\text{sec}}\right]^2\left[r\,(d/\text{in})^2\right]^2 \tag{6}$$

for strand loss calculation.

In these formulas f means frequency of the alternating current; r means the ratio of the width of the copper in the slot to the slot width times the ratio of the depth of conductor plus strand insulation to the net conductor depth; b means the ratio of the length of the slot to the length of a half turn; d means the depth of a strand; n means the number of layers of strands in the depth of the slot; and m means the number of turns per

1. See Appendix B.

coil[2]. The copper conductors have been assumed to be at 75 deg. cent. and the resistivity for this temperature has been used. The extra loss factors are inversely proportional to the square of the resistivity so that any other temperature may be evaluated if desired.

The quantity L which depends on the type of winding is calculated in Appendix A and is tabulated in Table I. The general method of calculating L for any type of winding is illustrated in Appendix A so that any reader who wishes to investigate types of windings outside the scope of this paper may do so.

Type	Description of Winding.	See Fig.	Value of L
I	Multiturn Coil, two coil sides per slot with an involute at each end. (Standard coil with which others are compared.)	1	$L = \frac{m^2-1}{4}$
II	All turns inverted on the end opposite the connections	2	$L = \frac{3}{4} - \sin^2 \frac{1}{2}\theta$ (m being odd)
		3	$L = -\frac{1}{4}$ (m being even)
III	All turns inverted on connection end	4 and 5	$L = 0$
IV	Top turn only inverted on connection end.	6	$L = \frac{(m-1)(m-2)}{m}\left[\frac{m^2-5m+2}{4m} + 2\sin^2\frac{1}{2}\theta\right]$
V	First half turn only inverted on end opposite connections.	7	$L = \left[\frac{m^4-4m^3+m^2+4m+1}{4m^2} + \frac{m-2}{m}\sin^2\frac{1}{2}\theta\right]$
VI	Bar---bottom coil side only		$L = \frac{m^2-1}{3}$
VII	Bar---Top coil side only.		$L = \frac{7m^2-1}{3} - 2m^2\sin^2\frac{1}{2}\theta$
VIII	Bar---Both coil sides.		$L = \frac{4m^2-1}{3} - m^2\sin^2\frac{1}{2}\theta$

Note: Top always refers to open end of slot

TABLE I—CIRCULATING LOSSES

It is shown in Appendix C that the extra loss factor in a laminated conductor of Type I may be calculated by the simple formula

$$k = 0.28\left[\frac{f}{60/\text{sec}}\right]^2\left[\frac{r\,b\,n^2\,(d/\text{in})^2}{m}\right]^2 \qquad (7)$$

for the first order of eddy currents with copper at 7 deg. cent[3].

2. The formulas are dimensionally correct and the quantities may be measured in any consistent system of units. They are so arranged that if f is measured in units of 60 cycles per second, and d is measured in inches, the calculation will be simplified. Thus d/in means the ratio between d and one inch. For example, if d were seven cm., the ratio would be

$$\frac{7\text{ cm.}}{\text{one in.}} \equiv 7 \times \frac{\text{one cm.}}{\text{one in.}} \equiv 7 \times 0.394 \equiv 2.76$$

As another example suppose that f is 60 cycles per second then

$$\frac{f}{60/\text{sec}} \equiv \frac{60/\text{sec}}{60/\text{sec}} = 1$$

but if f is 3000 cycles per minute

$$\frac{3000/\text{min}}{60/\text{sec}} \equiv 50 \times \frac{\text{one sec.}}{\text{one min.}} \equiv 50 \times \frac{1}{60} \equiv \frac{5}{6}$$

This system of dimensional formulas has been discussed by V. Petrovsky (see bibliography). He shows that it is unnecessary to have several formulas, one for each system of units.

3. First order of eddy currents means the eddy currents induced by the uniform current. They are expressed by the first term of an infinite series as shown in Appendix B.

The loss factors in any other type of transposed winding considered may be calculated by using the formulas for L given in Table I or by referring to the ratios given in Table II. Each formula in Table I and each ratio in Table II is given for a single coil, or group of coils, having a definite value of θ, which is the angular phase difference between the top and bottom coil side currents. Thus it is necessary to know from the pitch of the coils how they are distributed. Two factors must then be calculated and the weighted average taken to apply to the whole machine.

Extra loss factors obtained by the methods described are based on the assumption that the extra losses are not too large. Formula 7 may be used without sensible error provided the extra loss factor which it indicates does not exceed approximately 100 per cent. At this point the result is less than six per cent too large, but the error increases beyond this point. Even if the result is larger than 100 per cent it may still be used in combination with Table II provided the result for the type of winding under consideration is not too large. Thus it is clear that the approximate formulas are quite sufficient for any windings that would be allowed in practise.

It may be remarked in passing that the losses in bar windings may be calculated by formulas for coils of Type VI, VII and VIII given in Table I, and if the extra loss factor is large, the complete expression for M and N given in Appendix B should be used together with Equation (2) to obtain the total loss factor. Bar windings have been discussed fully elsewhere[4] and therefore are not treated in this paper.

m	TYPE II	II_a	II_b	II_c	II_d	III	IV	IV_a	IV_b	IV_c	IV_d	V	V_a	V_b	V_c	V_d
2	0.0164	0.0164	0.0164	0.0164	0.0164	0.262	0.262	0.262	0.262	0.262	0.262	0.0784	0.0784	0.0784	0.0784	0.0784
3	0.448	0.338	0.228	0.118	0.0074	0.118	0.0196	0.167	0.313	0.462	0.607	0.0565	0.0933	0.130	0.167	0.203
4	0.0041	0.0041	0.0041	0.0041	0.0041	0.0663	0.0197	0.207	0.393	0.579	0.765	0.195	0.226	0.257	0.289	0.319
5	0.162	0.122	0.0825	0.0426	0.0027	0.0426	0.0807	0.253	0.464	0.656	0.847	0.316	0.339	0.364	0.387	0.412
6	0.0018	0.0018	0.0018	0.0018	0.0018	0.0296	0.153	0.338	0.522	0.707	0.891	0.410	0.428	0.447	0.466	0.484
7	0.0827	0.0624	0.0421	0.0217	0.0013	0.0217	0.221	0.395	0.572	0.743	0.917	0.481	0.495	0.509	0.525	0.538
8	0.0010	0.0010	0.0010	0.0010	0.0010	0.0166	0.283	0.447	0.612	0.773	0.937	0.542	0.551	0.563	0.574	0.585
9	0.0502	0.0378	0.0254	0.0131	0.0008	0.0131	0.337	0.488	0.642	0.795	0.951	0.585	0.595	0.605	0.613	0.623
10	0.0007	0.0007	0.0007	0.0007	0.0007	0.0107	0.385	0.529	0.673	0.818	0.961	0.623	0.632	0.640	0.648	0.656

Note: Subscripts a, b, c and d refer to values of θ of 60°, 90°, 120° and 180° respectively.

TABLE II—RATIO OF EXTRA LOSS IN VARIOUS TYPES OF WINDINGS TO THAT IN TYPE I

STRAND LOSS

Up to this point the losses are supposed to be those which may be called circulating current losses and which would occur if the conductor were laminated by infinitely thin laminations. As intimated previously, there are additional losses which are due to the non-uniform distribution of current over the finite depth of the strands themselves. These losses may be approxi-

4. See bibliography.

mated by considering first that the current is uniform over the depth of the slot, and then calculating the eddy-current loss which would occur in the strands. This may be done by considering each strand to be a bar of a series-connected bar winding and applying formulas for coils of Type VI, VII, and VIII. It is shown in Appendix C that the strand loss may be approximated by

$$k_s = 6.0\, b\, \psi \left[\frac{f}{60/\text{sec}} \right]^2 [r\, n\, (d/\text{in})^2]^2 \qquad (8)$$

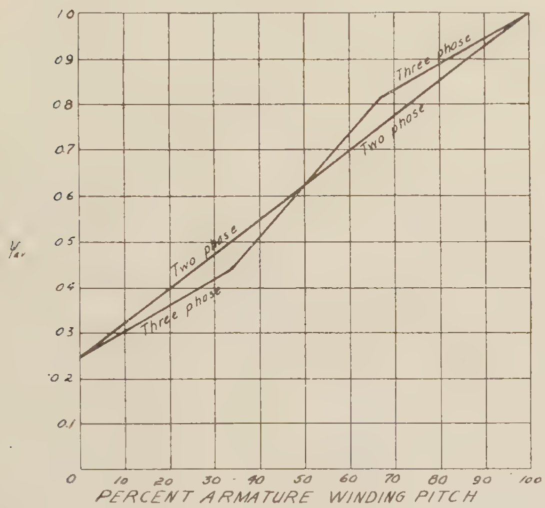

FIG. 8—THE FACTOR ϕ_{av} USED IN CALCULATING STRAND LOSS FACTOR

This value is different for each coil that has a different θ, and in general there are two groups of coils in a machine each having a different value of θ. It becomes convenient to average ψ over a whole machine so that the strand loss may be calculated easily. This has been done and ψ_{av} is plotted against per cent pitch in Fig. 8.

The strand loss factor is small in a well designed machine and may often be neglected when considering the effect of transposition. It is always present no matter what the transposition is and must be added to the circulating current loss factor to get the total extra loss factor for the first order of eddy currents. The strand loss may always be reduced by using finer laminations in the conductor.

To summarize the method of calculation of eddy-current losses it may be noted that an extremely simple slide rule calculation using Formula (7) will obtain the extra loss factor for a coil of Type I. The effect of transposition may be obtained from Table II by selecting a factor to apply to the extra loss factor for Type I. Finally the strand loss factor may be obtained by Formula (8) and added to the circulating current loss factor. The result is the total extra loss factor for the first order of eddy currents. This, multiplied by the normal copper loss of the winding, calculated for uniform current distribution, gives the extra loss due to eddy currents and is accurate, provided it be not so large that the first term of the infinite series discussed in Appendix B fails to properly describe it. If it should be as large as this, however, it would be too large to be considered permissible in a modern winding. A method of transposition would be selected to reduce it to a much smaller value.

An example will help to make these rules understandable. Suppose we are considering an hypothetical three-phase winding having coils of Type V, Fig. 7, with three turns, 17/24 pitch, and two coil sides per slot. Suppose the slot is 0.675 in. wide and each turn is composed of 30 strands, each 0.14 in. wide, 0.075 in. over the strand insulation, and 0.07 in. net depth, and arranged 3 wide and 10 deep. Suppose that the ratio of the length of the core to the length of a half turn is 0.50, and the frequency is 60 cycles per second.

Then

$$\frac{f}{60/\text{sec}} = 1$$

$$\begin{aligned} r &= 0.667 \\ b &= 0.50 \\ n &= 60 \\ d/\text{in} &= 0.07 \\ m &= 3 \end{aligned}$$

and

$$k = 0.28\,[1]^2 \left[\frac{0.667 \times 0.50 \times (60)^2 \times (0.07)^2}{3} \right]^2 = 1.07$$

A three-phase winding of 17/24 pitch has 87.5 per cent of the coils with an angle θ of 60 deg. and the rest with an angle θ of zero. Thus from Table II the proper factor is

$$0.875 \times 0.093 + 0.125 \times 0.056 = 0.0884$$

Therefore, the extra loss factor for the whole winding is

$$0.0884 \times 1.07 = 0.095$$

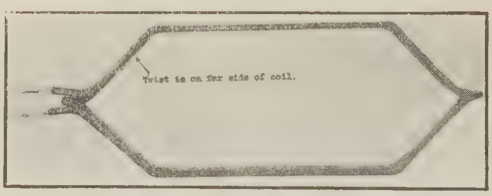

FIG. 9—COMPLETED FIVE-TURN COIL OF TYPE IV (SIMILAR TO FIG. 6)

or the extra loss due to circulating current is about 9.5 per cent of the ordinary copper loss, calculated for the square of the current and the ohmic resistance. Without the transposition, the formulas indicate an extra loss of about 107 per cent. The reduction from 107 per cent to 9.5 per cent by simply inverting the first half turn when winding the coil is quite a remarkable gain when the simplicity of the transposition is considered.

The strand loss factor to be added to the above in either case is

$k_s = 6.0 \times 0.50 \times 0.822\ [1]^2\ [0.667 \times 60 \times 0.0049]^2 \equiv 0.094$

and the total eddy current loss is about 19 per cent of the normal copper loss. This is a fairly high value for strand loss factor but it can be reduced by using smaller strands.

In all practical cases where there is more than one turn per coil, the extra loss may be kept down to a small fraction of the normal loss by using the proper inverted turn transposition. Where there is only one turn per coil the Roebel or 360-deg. transposition may be used. The discussion of this type of bar is outside the scope of the present argument and it suffices to say that it reduces the circulating current loss in a conductor to practically zero.

In conclusion the author wishes to express his appreciation of the invaluable suggestions of Mr. P. L. Alger and his enthusiastic support. He also wishes to thank Mr. M. C. Holmes for assistance with the numerical work in connection with the tables and for helpful criticism.

Appendix A

In order to illustrate the method of deriving the formulas shown in Table I, two of the cases are derived below. The others may be obtained in a similar manner and will not be proved here. Some of them have been derived previously by other writers but they were all checked in the preparation of this paper.

Consider Type III with an even number of turns. See Fig. 5.

Applying the rule given in the body of the paper

$$I_0 = \sum_{1}^{\frac{m}{2}} {}^{s}\ (p-1)\, I_1,$$

where p $= 2\,s - 1$ for all the odd half turns in the lower[5] coil side,

$$I_0 = \sum_{1}^{\frac{m}{2}} {}^{s}\ [(p-1) I_1 + I_2],$$

where $p = 2\,s - 1$ for all the odd half turns in the upper coil side,

$$I_0 = -\sum_{1}^{\frac{m}{2}} {}^{s}\ [(p-1)\, I_1 + I_1],$$

where $p = 2\,s$ for all the even half turns in the lower coil side, and

$$I_0 = -\sum_{1}^{\frac{m}{2}} {}^{s}\ [(p-1)\, I_1 + I_1 + I_2],$$

5. That part of the slot nearest the closed end is referred to throughout this paper as the bottom and that part nearest the open end, as the top.

where p $= 2\,s$ for all the rest.

Averaging these over the $2\,m$ half turns the result is

$$2\,m\,I_0 = \sum_{1}^{\frac{m}{2}} {}^{s}\ [(2\,s-2)\, I_1] + \sum_{1}^{\frac{m}{2}} {}^{s}\ [(2\,s-2)\, I_1 + I_2]$$

$$- \sum_{1}^{\frac{m}{2}} {}^{s}\ [2\,s\,I_1] - \sum_{1}^{\frac{m}{2}} {}^{v}\ [2\,s\,I_1 + I_2].$$

This gives

$$I_0 = -\, I_1$$

Hence

$$\left| \frac{I_0}{I_1} \right| = 1,$$

$$\text{Cos}\ \alpha = -\,1$$

and finally

$$L = 0.$$

Now consider Type IV. See Fig. 6.

In a manner similar to the first example

$$2\,m\,I_0 = -\sum_{2}^{m} {}^{p}\ [(p-1)\, I_1 + I_1] + \sum_{1}^{m-1} {}^{p}\ [(p-1)\, I_1 + I_2]$$

$$-\ [I_2 + (m-1)\, I_1 + I_1].$$

This reduces to

$$I_0 = \frac{(2-3\,m)\, I_1 + (m-2)\, I_2}{2\,m}.$$

Since all the conductors are in series

$$I_2 = m\, I_1 \angle\ \theta.$$

This is substituted and the vectorial summation effected so that

$$\left| \frac{I_0}{I_1} \right| = \frac{\sqrt{(2-3\,m)^2 + (m^2-2\,m)^2 + 2\,(2-3\,m)\,(m^2-2\,m)\cos\theta}}{2\,m}$$

and

$$\text{Cos}\ \alpha = \frac{(2-3\,m) + (m^2-2\,m)\cos\theta}{2\,m \left| \frac{I_0}{I_1} \right|}$$

and finally

$$L = \frac{(m-1)\,(m-2)}{m} \left[\frac{m^2 - 5\,m + 2}{4\,m} + 2\sin^2\frac{\theta}{2} \right].$$

Any combination of half turns may be calculated in a manner similar to the above and the reader may verify the rest of the formulas given in Table I or he may make new formulas for other combinations.

Appendix B

Non-uniform current distribution in armature conductors introduces changes in the effective reactance of the windings as well as in the resistance. The question of the reactance is not considered here. It is possible to set up equations containing complex numbers which express both the resistance and reactance factors, but since only the resistance is considered here M and N are taken[6] as

$$M = \text{real part of } q\,h \coth q\,h$$

$$N = \text{real part of } 2\,q\,h \tanh \frac{q\,h}{2}$$

where

$$q = \sqrt{\frac{8\,\pi^2\,j\,r\,f}{\rho}}$$

and h is the depth of the conductor.

It is always possible by means of the proper transposition to reduce the eddy current loss to a negligible fraction of the normal copper loss and it is therefore unnecessary to use the full expressions for M and N. They may be expanded into infinite series and all unnecessary terms dropped. Thus

$$M = 1 - \frac{4}{45}\,q^4\,h^4$$

$$N = -\frac{1}{12}\,q^4\,h^4$$

Let

$$q = (1 + j)\,g$$

so that

$$g = \sqrt{\frac{4\,\pi^2\,f\,r}{\rho}}$$

and

$$M = 1 + \frac{4}{45}\,g^4\,h^4$$

$$N = \frac{1}{3}\,g^4\,h^4 .$$

M appears in every expression for the circulating current loss factor. The constant part of it represents the normal copper loss while the variable part represents the extra loss. Thus the extra loss factor is

$$k = \frac{4}{45}\,g^4\,h^4 + \frac{L}{3}\,g^4\,h^4$$

or

$$k = [4 + 15\,L]\,D$$

where

$$D = \frac{g^4\,h^4}{45} .$$

6. See the paper by W. V. Lyon, bibliography 1.

The quantity h is the depth of one turn, while d is taken as the depth of one strand, m is the number of turns per coil, and n is the number of layers of strands in the slot, so that for a two-coil side per slot winding

$$h = \frac{n\,d}{2\,m};$$

for a one-coil side per slot winding

$$h = \frac{n\,d}{m},$$

and for strand loss calculation

$$h = d .$$

In a laminated winding the current is forced to flow over the whole length of a half turn by the voltages induced in the core portion only. The resistivity ρ is taken as $1/b$ times the actual resistivity for this reason where b is the ratio of the length of the core to the length of a half turn. Copper at 75 deg. cent. is assumed. Substituting the value of ρ and g, the value of D for a two-coil side per slot winding becomes

$$D = 0.075 \left[\frac{f}{60/\text{sec}} \right]^2 \left[\frac{r\,b\,n^2\,(d/\text{in})^2}{m^2} \right]^2$$

and for a one-coil side per slot winding, it becomes

$$D = 1.19 \left[\frac{f}{60/\text{sec}} \right]^2 \left[\frac{r\,b\,n^2\,(d/\text{in})^2}{m^2} \right]^2$$

and for strand loss calculation

$$D = 1.19 \left[\frac{f}{60/\text{sec}} \right]^2 [r\,(d/\text{in})^2]^2 .$$

Appendix C

Circulating Current Loss

The formula for a coil of Type I is taken from Table I and substituted in Equation (**3**), resulting in

$$k = \left[4 + \frac{15}{4}\,(m^2 - 1) \right] D,$$

or

$$k = \left[\frac{15}{4}\,m^2 + \frac{1}{4} \right] D .$$

The constant term in this expression may be dropped without fear of sensible error and the result is

$$k = \frac{15}{4}\,m^2\,D .$$

Substituting the proper value of D

$$k = 0.28 \left[\frac{f}{60/\text{sec}} \right]^2 \left[\frac{r\,b\,n^2\,(d/\text{in})^2}{m} \right]^2 .$$

Circulating current loss factors for any other type of winding may be calculated by selecting the proper factor

from Table II and applying it to the result just obtained. That is, the effect of the transposition on a coil of Type I is to reduce the extra loss in the ratio given in Table II. This table has been made up with the use of Table I and Formula (3.)

Strand Loss

The strand loss in a one-coil side per slot winding is obtained by substituting

$$L = \frac{m^2 - 1}{3}$$

in Formula (3.) The result is

$$k_s = \left[4 + \frac{15}{3} (m^2 - 1) \right] D$$

and this is practically equal to

$$k_s = 5\, m^2 D\ .$$

When the proper value of D is substituted

$$k_s = 6.0\, b \left[\frac{f}{60/\text{sec}} \right]^2 [r\, n\, (d/\text{in})^2\,]^2\ .$$

The factor b is introduced because the extra losses occur in the slot portion only.

In a two-coil side per slot winding

$$L = \frac{4\, m^2 - 1}{3} - m^2 \sin^2 \frac{\theta}{2}$$

and therefore

$$k_s = \left[4 + \frac{15}{3} (4\, m^2 - 1) - 15\, m^2 \sin^2 \frac{\theta}{2} \right] D\ .$$

Practically this is

$$k_s = 20\, m^2\, D\, \psi$$

where

$$\psi = 1 - \frac{3}{4} \sin^2 \frac{\theta}{2}\ .$$

The correct value of D is now substituted and b is introduced with the result that

$$k_s = 6.0\, b\, \psi \left[\frac{f}{60/\text{sec}} \right]^2 [r\, n\, (d/\text{in})^2\,]^2\ ,$$

This is the same result that was obtained for the strand loss in a one-coil side per slot winding where θ is zero, and is therefore general. Various coils in a machine may have different values of θ and it becomes convenient to have an average value of ψ to apply to a whole machine. This has been done and ψ_{av} is given in Fig. 8. For a three-phase machine ψ_{av} varies linearly from 1.0 at 100 per cent pitch to 13/16 for 66⅔ per cent pitch and from there linearly to 7/16 at 33⅓ per cent pitch and from there linearly to 0.25 at zero pitch. For a two-phase machine ψ_{av} varies linearly from 1.0 at 100 per cent pitch to 5/8 at 50 per cent pitch and from there linearly to 0.25 at zero pitch.

Table of Symbols

I_0	A quantity used in the formation of equations for extra loss. The rule for obtaining I_0 is given in the body of the paper.
I_b	The vectorial summation of all the current in the slot below the conductor in question.
I_1	The current in the conductor in question.
$\left\lvert \dfrac{I_0}{I_1} \right\rvert$	The numerical value of the ratio indicated.
α	The angle between I_0 and I_1.
L	A quantity which depends on the type of coil and its transposition. It is defined by Equation (1).
K	The ratio of the total heat loss in the coil to that due to uniform current distribution.
k	The ratio of the extra heat loss in the coil due to eddy currents to that due to uniform current distribution. Also called extra loss factor due to circulating currents.
D	A quantity depending on the dimensions of the slot and coil, the frequency, the number of turns per coil, and the number of coil sides per slot. It is defined in Equations (4), (5) and (6).
f	The frequency of the alternating current.
r	The ratio of the width times the overall height of the copper conductor in the slot to the slot width, times the net conductor height.
b	The ratio of the length of the slot to the length of a half turn.
d	The depth of a strand.
n	The total number of layers of strands depthwise in the slot including both coil sides.
m	The number of turns per coil.
k_s	The ratio of the extra loss due to strand loss to that due to uniform distribution of current. Also called strand loss factor.
p	The order of the conductor under consideration. The one nearest the bottom of the slot in the coil side under consideration is $p = 1$. The effect of eddy currents is calculated by averaging I_0 over all conductors and is accomplished by finding I_0 for the general conductor p and summing up all such values.
s	Any integer. The summations in Appendix A are effected with respect to s between the limits indicated.
h	The depth of a conductor, or turn.
q	A quantity depending on frequency, resistivity of the conductor, width of conductor, width of slot, length of slot, and length of a half turn. It is a complex quantity.
j	The square root of minus one.
g	The quantity q divided by $(1 + j)$. It is real.
ψ	A quantity used in strand loss calculation. It is $\psi = 1 - (3/4) \sin^2 (\theta/2)$.

ψ_{av} The quantity ψ, averaged over all the coils in a machine.

ρ The resistivity of the conductor.

θ Angular phase difference between the currents in the top and bottom coil sides in one slot.

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Abridgment of

Klydonograph Surge Investigations

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Synopsis.—*Since its recent development, the klydonograph has been used to investigate surge conditions on a number of transmission systems. Quantitative data, which show the characteristics of the actual surges present on transmission systems, are presented. In addition, these data are discussed in relation to various existing theories and practises regarding the production and the elimination of transient high voltages. The correctness of some of these ideas and the fallacy of others are indicated. The paper is subdivided, according to the nature of individual investigations, as follows:*

I. Open-wire Systems.

II. Cable Systems.

III. Lightning Arresters.

INTRODUCTION

THE development of the klydonograph [2,3,4] in 1924, by Mr. J. F. Peters, gave promise of settling the long-standing question of the prevalence of surges on transmission systems. Since the spring of 1925, 26 three-terminal klydonographs have been in almost continuous operation on many systems of widely varying characteristics. Work has been concentrated on open-wire systems during the lightning seasons and on cable systems at other times.

In most cases, the klydonographs were connected and calibrated to measure the crest values of surges between conductors and ground. Therefore, the surge voltages have been referred to the "normal operating crest voltage to neutral." Where the term "times normal" is used, it refers to the magnitude of the surge, on this basis. It has been the practise to adjust the potentiometers, through which the klydonograph is connected to a system, so the operating voltage gives a potential of approximately three kilovolts crest at the instrument terminals. This arrangement permits the measurement of voltages of from seven to ten times normal. Beyond this, the magnitude is estimated from the degree of spreading of the figure, or from the violence of the instrument flashover.

In addition to the investigations for the purpose of measuring transient voltages, arrangements were made to record the performance of lightning arresters on certain systems. The arrester-discharge current and the surge voltages to ground at the arrester terminals were the quantities measured.

The data have been divided into three parts, according to the nature of individual investigations:

I. Open-wire systems,

II. Cable systems,

III. Lightning arresters.

I. OPEN-WIRE SYSTEMS

Surges on open-wire transmission systems are of interest to the operating engineer, chiefly on account of the flashovers and consequent interruptions, which follow. Although high voltages have a deteriorative effect on apparatus insulation, and although the life of this insulation probably is shortened by such surges, the effect on continuity of service usually is regarded as the more important point. The comparative freedom of high-voltage apparatus from failures justifies this opinion.

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1. Westinghouse Electric & Mfg. Company.
2. The Klydonograph, J. F. Peters. *Electrical World*, April 19, 1924.
3. *The Klydonograph and Its Application to Surge Investigations*, J. H. Cox and J. W. Legg. TRANS. A. I. E. E., Vol. XLIV, 1925.
4. *220-Kv. Transmission Transients and Flashovers*, R. J. C. Wood. TRANS. A. I. E. E., Vol. XLIV, 1925.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

Consequently, in summarizing the data, the number of surges, rather than the number of indications, has been considered. For example, if high voltages appeared on more than one conductor, or at more than one point of a line simultaneously, they have been regarded as one surge. Obviously, such a surge could cause only one interruption, regardless of the voltages existing on individual phases or at various points. The maximum value and its polarity have been used in classifying the magnitude and the polarity of each surge, in the tables.

Aggregate data for all systems are classified according to surge causes in Table IV. All data have been brought to a common basis of ten years operation of one three-terminal klydonograph at one point of each system. The relatively long period of ten years was chosen to avoid fractions for high-magnitude surges, which were of infrequent occurrence. Since the lightning season usually is regarded as six months, the constant used where lightning surges were involved, is one-half the value applied to all other surges. Although many investigations lasted only a few months, and although some were conducted at such times that no lightning data were obtained, the tests were sufficiently extensive to warrant some important conclusions.

Lightning. As shown by Table IV, the majority of lightning surges were positive. However, all the highest surges were negative, but they were infrequent. The highest positive surges only slightly exceeded ten times normal, while negative surges sometimes were considerably beyond this value. In three cases, direct strokes were known definitely to have caused the large negative records. In view of the fact that an induced surge is of opposite polarity, and that a surge, due to a direct stroke, is of similar polarity, to the charged cloud, it is concluded that those clouds, which cause surges, are of negative polarity[5].

The occurrence of a flashover following a surge depends upon the wave-front, as well as upon the magnitude, of the transient voltage. The maximum possible potential, induced by lightning, is the product of the field gradient destroyed by the stroke, and the height of the line. It has been estimated that gradients as high as 100 kv. per foot (330 kv. per meter) are reached near the earth's surface; 60 kv. per foot (200 kv. per meter) has been measured. It is universally assumed that cloud-field gradients are constant for the height of a transmission line. Thus, extremely high induced potentials are possible. However, the extreme voltages are induced only near the discharge path. From this point to the boundary of the field, the gradient decreases rapidly.[6] The rate of rise of potential, on that part of the line directly in the cloud field, is equivalent to the rate of collapse of this field. Where negative clouds are concerned, it is believed that the collapse takes place in a time of the order of three microseconds. Upon the release of the bound charge, it divides and travels along the line in both directions. On points of the line outside the cloud field, the rate of rise of potential is determined by the front of the traveling wave. With the rates of discharge mentioned above, the front of this traveling wave is determined chiefly by the space configuration of the charge. Klydonograph data indicated that lightning surges have wave-fronts varying from a few to 200 microseconds. The higher-voltage surges had the steeper wave fronts. This conforms with the above discussion. Also, it is well known that the potential, which can be applied to any insulation, increases with the rate of application of the voltage. However, the time lag of the flashover of insulators decreases as the potential, in excess of the 60-cycle flashover voltage, is increased. Thus, the potential, that can be applied at any given rate of application, is limited, and similarly the maximum voltages, reached by lightning surges of even the steepest wave fronts, are limited by insulator flashovers. These flashovers permit the charge to pass to ground. The limitation of voltage is indicated by the fact that, on systems of widely different voltages, the maximum surges were approximately the same number of times the operating voltages. However, the data are not conclusive on this point, owing to the limitations of range of the klydonograph. More definite information was obtained on a 55-volt signal circuit. Since this circuit was only 2.5 miles (4.0 km.) long, any surge induced upon it would have been detected. This line flashed over repeatedly during lightning storms, but the potentials never exceeded 10 kv.

In this connection, it is believed that the flashover voltage of 220 kv. transmission-line insulation, at the steepnesses of wave-front of lightning surges, is comparable to the maximum potential ordinarily induced by lightning. Thus, lines of this voltage should be practically immune to lightning, with the exception of direct strokes.

The number of important surges which appear at a given point of a line during one lightning storm, was found to be low. More than two surges in excess of seven times normal voltage seldom were recorded at one klydonograph station. Also, many apparently severe storms were experienced without recording these higher voltages. Of course, their presence on a line depends, to a certain extent, on its length; the greater the exposure, the greater is the probability of lightning voltages at some point. The distance, from the point of origin, over which a surge maintains a magnitude of several times normal, is not definitely known. However, this appears to be of the order of a very few miles. It is hoped that accurate information on this point will be secured in the near future. In the meantime, the fact that only about two surges per storm occur, has

5. *Transmission Line Voltage Surges, J. H. Cox, A. I. E. E.* Journal, March, 1927.

6. *Lightning and Other Transients on Transmission Lines,* F. W. Peek, Jr., Trans. A. I. E. E., Vol. XLIII, 1924.

considerable significance in connection with the application and operation of protective equipment.

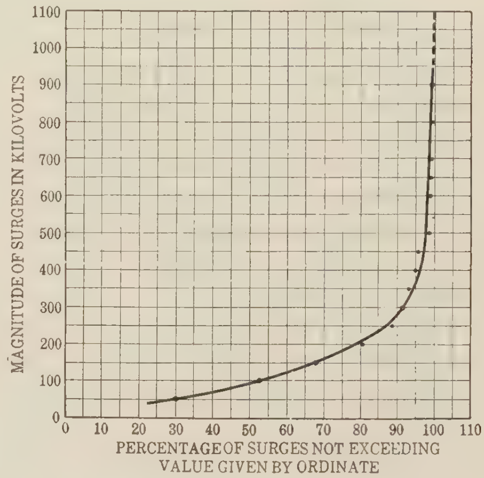
A rather striking freedom from surges on the lower voltage lines, which operating statistics hardly verify, also was noticed. Higher, and more frequent surges, since lower induced-voltages must be considered, would be expected. For example, a lightning surge of 100 kv. would be 1.8 times normal on a 66-kv. line, but 5.4 times normal on a 22-kv. line. It is true that low-voltage lines are better protected from the field of influence of the cloud, because they are invariably nearer the ground than high-voltage lines. Consequently, lower induced voltages are to be expected, but this factor is not great enough to account for the results mentioned above. A number of possible explanations have been considered but, to warrant definite conclusions, further investigation is necessary.

Certain localities are nearly immune from lightning. Sometimes these are found even adjacent to regions where lightning is severe. On a system with lines extending in opposite directions from the same station, lightning conditions were found to be severe on one of these lines, and mild on the other. The freedom from trouble of the latter had been attributed to certain features which had been incorporated in its construction. This illustrates the error of drawing conclusions regarding the efficiency of protective devices from an individual application.

In Table IV, a distinction is made between those surges which caused flashovers and those which did not. As would be expected, all the higher surges caused flashovers. A wide variation exists in the amount of insulation used on lines of the same voltage. However, a measure of the flashover value of the average insulation, for the wave-fronts produced by lightning, is indicated. Surges, which were over seven times normal and did not cause flashovers, were recorded on only one system.

The majority of the low-voltage surges are listed as "not causing flashovers." However, several surges of low magnitude are listed as "causing flashovers." Doubtless, the latter were of much higher magnitude at some point of the line remote from the klydonograph. It was found that high-voltage surges did not travel far. In traversing a few miles of line, they were always damped to a small fraction of their initial value. In several instances, a decrement from over 1000 kv. to about 150 kv. was observed over a distance of 35 miles (56 km.). In one case, a surge five times normal was recorded five miles (eight km.) from a direct stroke, which caused a flashover to ground in the middle of a long span. Thus, it appears that the higher-voltage surges are damped below the corona voltage in about 10 miles (16 km.). When this has occurred, the surge may travel a considerable distance without much attenuation. Frequently a surge of the order of 1.5 or 2.0 times normal, traveled 50 miles (80 km.), and occasionally, the entire length of a 250 mile (400 km.) line.

The data show that lightning voltages are unidirectional. When a flashover occurred, the klydonograph often indicated an oscillatory surge. Most of the oscillatory records are found in the column "causing flashovers." However, there are a few in the other column. These were probably due to surges producing lightning arrester discharges or flashovers on con-



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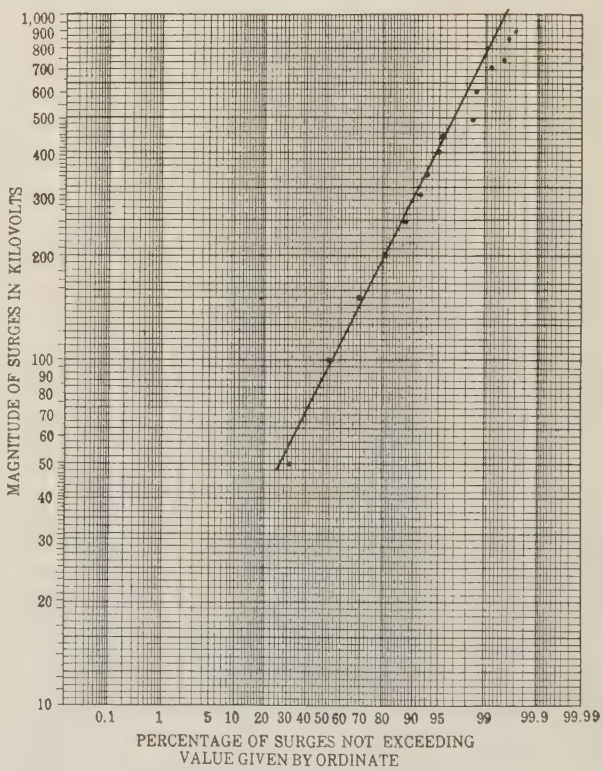

B

Figs. 1a, b—Relative Percentage of Lightning Surges of Various Magnitudes

necting lines, which were overlooked in collecting the information.

The lightning data are plotted in Figs. 1a and 1b. The voltages produced by lightning are a function of the heights of lines, and not of the operating voltages,

except as limited by the flashover of insulators. Therefore, in view of the variation in the operating voltages of the lines tested, the curves have been drawn with ordinates in kilovolts rather than "times normal" although the latter is a better criterion of the severity of a particular surge. The plotted results include all the data from the 27 tests. Fig. 1A is plotted in Cartesian coördinates and shows the relative percentages of lightning surges of different magnitudes. Fig. 1B represents the same quantities plotted on probability paper. The exceedingly small percentage of the total, of the higher-valued surges, is illustrated in Fig. 1A. The reasonable conformity of the plotted results to a straight line in Fig. 1B indicates that sufficient data to represent true conditions were obtained, and that the magnitudes of lightning surges follow the law of probability. The plotted results deviate slightly from the straight line at the higher values. This is explained by the fact that, on the lower-voltage lines, insulator flashovers limited the magnitudes of many surges, which otherwise would have reached higher values.

Various authors have discussed the value of the ground wire for reducing potentials induced on transmission lines by lightning. The theory of ground wire performance is relatively simple. It rests on the assumption that the charge on the ground wire can pass to ground as rapidly as the cloud discharges. The conclusions regarding the rate of lightning discharges indicate that this assumption is justified. Calculations based on this theory show that, with typical spacings, the ground wire reduces by 25 to 45 per cent, the potentials induced on the conductors. Using small-scale models, F. W. Peek, Jr., obtained test results which indicate reductions as high as 50 per cent[6]. The percentage protection against flashovers is much greater than the percentage reduction of induced voltages. This is for the reason that, on high-voltage lines, many of the induced surges which cause flashovers are not greatly in excess of the flashover voltages of the lines. It is readily conceivable that complete freedom from induced-voltage flashovers might result from a 50 per cent reduction of these voltages[7].

Induced lightning voltages, simultaneously recorded on the three phases of vertically-spaced lines, were highest on the top phase and lowest on the bottom phase, particularly where no ground wire was installed. Operating records also indicated that most flashovers occurred on the top conductor. According to the theory of the ground wire, with the usual spacing arrangement, the greatest protection is afforded the top conductor, which needs it most. Hence, the relative voltages appearing on the conductors, where a ground wire is installed, are a compromise between the respective induced voltages, as affected by the heights of the conductors, and the respective reductions effected by the ground wire.

Because of the impossibility of obtaining lightning conditions at different times known to be similar, it is difficult to secure definite field data on the utility of the ground wire. However, a tendency in its favor was noted. On those lines equipped with a ground wire, the proportion, of surges over five times normal to the total, was less than on lines without a ground wire. The most conclusive evidence was obtained on a system on which a ground wire was installed between the summers of 1925 and 1926. It was noticed that, after the ground wire was installed, there were no induced surges above five times normal. The number of direct strokes remained practically the same. However, it is not expected that a ground wire will render the line immune to direct strokes. It may be argued that these results are due to the vagaries of lightning, rather than to the efficiency of the ground wire. But, the fact that there were nearly as many direct strokes the second year, indicates that the lightning season was nearly as severe. Furthermore, the operators were of the opinion that the improvement in their operating record was more pronounced than can be accounted for by the difference in the lightning encountered.

Switching. Switching surges are not a serious problem where the present accepted factors of safety for insulation are used. The maximum switching surge recorded was six times normal. Surges of this kind over 4.5 times normal were found on only five of the 27 systems investigated. On 15 of these systems, no switching surge over three times normal appeared. The majority of all switching surges were below this value.

Not all switch operations produce surges. On one system, the tests covered a period during which 3600 high-tension switching operations were performed. Approximately three-quarters of these caused no surges that were detected at the stations, although there were klydonographs at each of the high-tension switching points. Of those surges recorded, 93 per cent were less than two times normal. Thus, only 1.75 per cent of the switching operations caused surges over two times normal. The maximum surge recorded on this line was 3.2 times normal. It is estimated from the data for the 27 systems, that, on the average, less than one-half of all switching operations caused surges above normal voltage.

As shown in the table, 80.8 per cent of all switching surges recorded, were less than two times normal, 93.0 per cent were less than three times normal, and 99.2 per cent were less than 4.5 times normal.

The higher-magnitude surges were recorded on lines of 66 kv. to 140 kv. No surge as high as 4.5 times normal appeared on systems below 66 kv. With one exception there were none as high as three times normal. The absence of the higher surges on the lower-voltage lines is attributed to the fact that, in these cases, the

7. *Discussion at Niagara Falls Convention, May 1926.* J. H. Cox. JOURNAL, A. I. E. E., October, 1926, Page 1028.

klydonographs were usually connected to busses with many connected lines.

Little difference between the switching surges on systems with free and grounded neutrals, was detected. A grounded conductor on a free neutral system during switching operations accentuates the surges produced, by the factor 1.73. The actual surges over 4.5 times normal were caused by closing operations, when one conductor was grounded. They were all 5.2 times normal. On one system, the actual surges over 4.5 times normal, listed under "closing switches at klydonograph stations," were caused by closing a 100-mile (160-km.) line and synchronizing with the power plants. All of these were 4.6 times normal.

Load switching does not cause surges as high as idle-line switching. This was found to be the case on all systems. With few exceptions, the surges caused by de-energizing idle lines are appreciably the highest of all switching surges. Of all the surges due to switching operations at the klydonograph station, 57.5 per cent was caused by opening operations and 42.5 per cent by closing operations.

It was found that switching surges occasionally traveled considerable distances. This is because they were low in magnitude, and thus, not affected by corona. In other words, they were governed only by the resistance term of the attenuation constant.[5] Surges due to closing operations were recorded at distant stations oftener than those due to opening operations. Of all the surges recorded at distant stations, 53 per cent were caused by closing and 47 per cent by opening operations.

It is interesting to note that changing taps on a transformer under load produced no surges. In general, charging electrolytic lightning arresters did not cause surges. However, on one system where the arresters were not equipped with charging resistors, oscillatory surges as high as 2.4 times normal sometimes resulted. On other systems an occasional surge about 1.3 times normal was produced.

Switching surges were quite abrupt when generated, the fronts being of the order of one microsecond. They were damped rapidly and the fronts became more sloping. The greater the distances from the switch the longer were the fronts. The wave fronts of the switching surges recorded were from one microsecond to a few hundred microseconds.

Switching surges were of short duration: 86.6 per cent were unidirectional and 13.4 per cent were oscillatory. On one system, the majority of the surges were oscillatory. These were caused by interrupting the charging current of appreciable sections of line with disconnect switches. When reflections occurred and produced an oscillatory record, the surge lasted only one or two cycles. Further, the initial voltage was always appreciably higher than the succeeding half cycles. This indicates rapid damping, and consequently, the time of application of the high voltage was of short duration.

In view of (a) the moderate magnitude, (b) the low frequency of occurrence, and (c) the short time duration, of the higher surges due to switching operations, they are not of serious importance either from the standpoint of continuity of service or of the effect on the life of apparatus insulation.

Flashovers and Interruptions. Flashovers in general

TABLE IV

SUMMARY OF SURGES IN 10 YEARS AT ONE STATION ON EACH OF 27 OPEN-WIRE SYSTEMS

Cause	Type*	Below 2.0 times normal	2.0–2.9	3.0–4.4	4.5–6.0		
Opening a switch at a station where a klydonograph was located...	U	6000	960	700	49		
	O	750	260	95	20		
Closing a switch at a station where a klydonograph was located...	U	4300	650	280	45		
	O	710	360	120	60		
Opening switches at other stations..........	U	2300	100	100			
	O	230	44				
Closing switches at other stations..........	U	2700	220	20			
	O	200	8				
Shortcircuits and flashovers other than those due to lightning......	U	290	64				
	O	680	390	240	27		
Interruptions..........	U	1200	180				
	O	320	210	80			
Unknown..........	U	8200	1300	270	37		
	O	1000	450	140	28		
		Below 2.5	2.5–3.4	3.5–4.9	5.0–6.9	7.0–9.9	Over 10.0
Lightning which caused a flashover..........	P	1600	290	200	26	112	50
	N	71	38	110	68	160	88
	O	810	400	84	110	47	
Lightning which did not cause a flashover..........	P	3200	550	230	170	27	
	N	5	32	17	2		
	O	350	14	54		27	

*U = Unidirectional. O = Oscillatory. P = Positive. N = Negative.

are objectionable from the standpoint of service interruptions. In some cases, they result in damage to the line in places where the repairs require considerable time and inconvenience. Also, the question of the effect of flashovers at one point, on the rest of the system, has often been raised.

Apparatus and line failures have been blamed on the suspected presence of high-frequency high-voltage oscillations. Klydonograph records show that, on grounded neutral systems, no serious high-voltages are produced by flashovers and no sustained high-frequency disturbances are produced by flashovers or by other causes. Sometimes small surges occur, due either to the fault or to the resulting switch operation—there is no way to distinguish between these causes. However, these surges are small and unimportant.

In the table, surges are classified as unidirectional or oscillatory. The latter classification really includes two types of surges. One is a highly damped oscillation of one or two cycles, the successive half cycles being much reduced in magnitude. These surges are really similar to unidirectional ones, in their effect. They sometimes occur in connection with switching, lightning, or flashovers on grounded neutral systems. Their oscillatory nature often is due to reflections in the circuits.

Oscillatory surges of the other type are sustained high-frequency oscillations. These occurred only on ungrounded neutral systems after flashovers, which result in arcing grounds. The frequency of these ranged from 2000 to 30,000 cycles per second; their maximum voltages were sometimes 4.5 times normal. The oscillations resulting from arcing grounds extended to all parts of the system.

It is known that the breakdown voltage of air is reduced, if the frequency of the applied voltage is high enough to maintain the ionization of the air from one cycle to the next. Thus, the ionization is cumulative, and the breakdown is progressive. Such a breakdown will occur at a point below the 60-cycle breakdown voltage.

In recent years, certain devices, which were designed to prevent insulator flashovers from such disturbances, have been placed on the market. But sustained high-frequency oscillations occur only on isolated neutral systems, and there, only after a flashover. Obviously, it is futile, even on free neutral lines, to install devices designed to prevent flashovers due to this type of disturbance. Since, on long lines, the service is already impaired, protection against the second flashover is of minor importance. It is encouraging to know that no sustained high-frequency, high-voltage disturbances need be feared on grounded-neutral systems.

No high-magnitude surges resulting from interruptions other than those due to flashovers were recorded. The surges found were low in value. In most cases they were less than twice normal. The highest recorded were less than 4.5 times normal and these occurred on only two systems. These results are consistent with the data on switching operations. Surges due to switching load currents always were low.

The surges listed as unknown were probably caused by switching or lightning, but incomplete operating records prevented the detection of the causes. They were relatively low in magnitude and warrant no further consideration.

The tests on open-wire systems show that, except for lightning and arcing grounds no high-voltage disturbances of particular importance to the operating engineer, are present.

II. Cable Systems

During the past two years, surges on cable systems have been investigated with the klydonograph. The information obtained in fourteen of these investigations is presented here.

In order to bring the data from various systems to a comparative basis, the records have been weighted to represent one year's operation of one three-terminal klydonograph on each system. The total number of voltage indications has been counted; for instance, if two or more abnormal voltages were recorded simultaneously on different phases or at different points of a system, each has been considered individually. While these methods of analysis have some undesirable features, it is believed they provide the most satisfactory comparison from the point of view of the effect of surges on insulation, which is the prime consideration.

Summarized data are shown in Tables V and VI. The former classifies the surges according to their causes; the latter demonstrates the variation between particular systems. In order to visualize these results as applied to the average system, they may be regarded as representative of the total number of surges to be expected at a given point of the average system in a period of fourteen years. Of course, this assumption has limitations—as will be seen later.

The klydonographs were usually connected to a system at generating stations or substations, and measured the surge voltages between the conductors and ground. All magnitudes were calculated with "times normal crest voltage to ground" as a unit. The highest voltage recorded was 4.6 times normal. Only 10 surges or 0.4 per cent of the total were over four times normal. Of these, six were on one cable-and-open-wire system, where certain contributory operating conditions prevailed. Only one of these high surges was on a pure-cable system[8]. Nearly 99 per cent of the total were under three times normal voltage. Also 92 per cent of the total were unidirectional and, therefore, of brief duration. Most of the abnormal voltages were caused by normal switching operations, and it is believed that many of those

8. It is realized that a "pure-cable" system possibly does not exist literally. However, the term is used here to classify those systems where cables strongly predominated, or where open-wire transmission lines were sufficiently remote to have no effect on surge conditions at the points investigated.

TABLE V
SUMMARY OF SURGES IN ONE YEAR AT ONE POINT ON EACH OF 14 CABLE SYSTEMS

	Number of surges									
	Times normal voltage				Unidirectional		Oscillatory			
Cause	1.1 to 1.9	2.0 to 2.9	3.0 to 3.9	4.0 to 4.9	1.1 to 2.5	2.6 & over	1.1 to 2.5	2.6 & over	Total	Per cent total
Closing a switch at a station where a klydonograph was located	1050	92		1	1120	23			1143	42.4
Opening a switch at a station where a klydonograph was located	340	25		1	360	6			366	13.6
Switching at other points of the system	117	13	5		120	15			135	5.0
Cables failures, automatic interruptions	300	49	13	5	150		185	32	367	13.6
Unknown	660	12	5	3	645	23	12		680	25.4
Total	2467	191	23	10	2395	67	197	32	2691	
Per cent total	91.6	7.1	0.9	0.4	89.0	2.5	7.3	1.2		100

TABLE VI
SHOWING THE VARIATION IN SURGE CONDITIONS ON INDIVIDUAL CABLE SYSTEMS. FIGURES ARE FOR ONE YEAR'S OPERATION OF A THREE-TERMINAL KLYDONOGRAPH ON EACH SYSTEM

	Uni-directional				Oscillatory			
	No. of surges				No. of surges			
System Cable and open wire	1.1 to 2.5 times normal	2.6 & over	Max. times normal	Per-cent total	1.1 to 2.5	2.6 & over	Max. times normal	Per-cent total
24 Kv	13		2.4	68	4	2	3.0	32
26 Kv	30		1.7	100				0
26 Kv	250	30	4.3	91	27		2.4	9
26 Kv	140	7	3.3	73	27	26	4.6	27
33 Kv	12	4	3.1	89	2		1.8	11
66 Kv	215	13	4.7	96	10		2.4	4
Cable only								
11 Kv	140	2	2.6	91	15		1.8	9
13 Kv	320		1.8	98	5		1.3	2
13 Kv	320		1.5	97	11		1.4	3
13 Kv	600	9	2.6	100				0
13 Kv	105	2	4.5	69	48		2.3	31
26 Kv	38		2.6	44	46	2	2.6	56
33 Kv	87		1.4	100				0
45 Kv	125		1.6	97	2	2	2.6	3
	2395	67		92	197	32		8

tabulated as unknown were also due to switching. Klydonograph clock errors and incomplete operating records undoubtedly prevented linking up a surge with its cause in many cases.

However, the surges produced when failures occurred were considerably more severe than those due to switching. Practically all the oscillatory surges, and particularly the higher-voltage ones, were caused by insulation breakdowns. That these surges were the effects, and not the causes, of insulation failures is strongly indicated by the fact that they did not occur unaccompanied by a short circuit. Surges of this nature invariably appeared on the two phases of the system other than the faulty one, with about the same magnitude on each. The theory of production of surges of this nature involves the characteristics of the arc. This theory calls for a maximum of 2.5 times normal voltage for surges due to arcing grounds on grounded neutral systems[9]. The results for all except one system check very closely with this value. A maximum of 2.6 times normal was recorded on these systems. Allowing for errors of measurement, the agreement is very satisfactory.

The relatively greater severity of surges due to short circuits is because of the following considerations. These surges affect a large part of a system. In many cases, appreciable voltages were recorded many miles from the location of the failure. As a rule switching surges failed to travel far. In addition, surges accompanying short-circuits usually were oscillatory, while switching surges were unidirectional. Thus, it is seen that, for a given magnitude, surges resulting from short circuits are more severe on insulation. This is due to their longer time of application and to their greater energy which results in more of the system insulation being stressed. But the elimination of insulation failures would automatically eliminate surges of this class.

In addition to the surges included in the tables, there were many recorded when energizing and de-energizing short bus-sections or leads to the klydonograph equipment, or, in other words, where very small charging currents were involved. These reached a maximum of 4.5 times normal voltage, those for energizing operations averaging somewhat lower magnitudes. However these voltages appeared only on the sections being switched, involved very little energy, and usually were not the result of normal switching operations. For these reasons they are not included in the data. Certain physical conditions, which give the proper proportions between inductance and capacity, with high leakage resistance, are apparently necessary for the production of the higher voltages. Consequently, the great majority were of the order of two times normal or less. Surges, due to actual cable switching or operations involving appreciable currents, failed to reach three times normal voltage. In general, the production and magnitude of switching surges appear to be haphazard affairs and, for a given operation, no relation between the magnitudes on the various phases can be detected.

The large number of small surges shown for certain systems is somewhat due to the influence upon the tabulated data, of special switching tests or other-than-

9. *Voltages Induced by Arcing Grounds.* J. F. Peters and J. Slepian; TRANS. A. I. E. E., Vol. XLII, 1923.

normal cable switching operations. The latter were necessary, in some cases, for changing the plates or films in the klydonographs.

It will be noted in Table VI that the surges on cable-and-open-wire systems were somewhat higher than those on pure-cable systems. This is partly due to the presence of lightning voltages on open-wire systems, although surges of this nature were eliminated from the data where known to be such. Incidentally, none of these known lightning surges were of a magnitude to make them important. Again, transmission line switching usually results in higher surge voltages than similar operations involving cables. One surge 4.5 times normal was recorded on a pure-cable system. However, this was due to energizing a switch group, which is a low energy operation as discussed above, but, at the same time, routine switching. Otherwise, the highest voltage observed on a pure-cable system was 2.6 times normal.

An interesting phenomena has been observed in connection with cable failures on four or five occasions. During three to six hours before the breakdown a succession of surges of the order of 1.7 times normal voltage has been recorded on two phases of a system, with the final breakdown occurring on the third phase. In other words the fault made itself evident sometime before the short circuit developed. The klydonograph records indicated that this was not a continuous process but occurred more or less irregularly at intervals of a few minutes. Apparently, impulsive discharges through temporary punctures of the insulation took place. These created sufficient unbalance to raise the other phases to approximately the delta voltage above ground for an instant, without developing into a short circuit severe enough to cause an interruption. This action has been noticed only on 26-kv. and 33-kv. systems, and in each case the system neutral was grounded.

Apparently, transient high-voltages are a very minor contributory factor to cable-insulation failures. Considering the test voltages which cables are required to withstand for an appreciable time, it also appears that surges cannot be held responsible for the failures encountered in practise. This conclusion is reached by virtue of the low magnitude, the short time duration and the low frequency of occurrence of surges. It might be argued that it is wrong to assume that very high voltages occur nowhere on a particular system because none appeared at certain points studied for a limited period of time. However, the data were obtained on several systems and under a wide variety of operating conditions. The rarity of surges of even four times normal voltage naturally leads one to doubt very strongly the existence of higher transient voltages on cable systems. Of course it is conceivable that surges, of the order of magnitude found in these investigations, might cause a failure, if the insulation at any point were to reach such a condition that a slight increase in potential would break it down. But it is doubted that these surges could create this abnormal condition and its elimination would be the primary problem.

III. Lightning Arresters

The klydonograph has proven valuable for recording the performance of lightning arresters under operating conditions.[10] The magnitude and nature of the arrester discharge current as well as the same quantities for the impressed voltage surge can be determined. The current measurement is obtained by recording the voltage drop across a non-inductive resistor, which is inserted in the arrester ground lead. A 10 to 15 ohm resistor is suitable. Since the minimum recording voltage of the klydonograph is about 2000 volts, the detection of currents above 150 to 200 amperes is possible with this arrangement. On three-unit arresters the bases must be insulated from their supporting foundations to force current through the resistance shunt. The voltages measured at the terminals of the arrester are the maximum values reached by the surge at that point. These exist for the very brief interval required for the arrester to come into operation, after which they are reduced by the discharge. However, the extreme speed of the klydonograph permits the measurement of these short-duration peak values.

Unfortunately, in most of the tests it was not feasible to install equipment to measure the surge voltages on all three phases. Where this was the case, the highest conductor, or the highest and the lowest conductors, were selected, for the reason that induced lightning voltages vary as the heights of the conductors above ground. However, the voltages impressed on the arrester terminals, may not correspond to this law, if a flashover occurs at some distance from the arrester, or if transpositions are frequent.

In Table VII the data on the performance of lightning arresters are listed. All the arresters tested were of modern valve type. In order to bring the data from individual tests to a common basis, the records have been multiplied by a factor to make then represent the operation of each arrester for one lightning season of six months. Classification has been made according to the maximum recorded voltage of each surge. The divisions are: (a) Above 3.5 times normal; (b) 3.5 to 2.6 times normal; (c) below 2.5 times normal; (d) discharges recorded on arresters on which no potentiometers for measuring voltage were installed.

The basis of most apparatus insulation tests is twice the operating phase-to-phase voltage. Consequently, lightning arresters are adjusted to relieve surges above this magnitude. However, all surge calculations have been based on the normal crest voltage to neutral. Therefore, a surge $2 \times 1.73 = 3.5$ times normal in the tables, corresponds to twice the phase-to-phase crest

10. Arrester Tests with the Klydonograph, L. R. Golladay. *Electrical World*, Sept. 4, 1926.

TABLE VII
SUMMARY OF LIGHTNING ARRESTER INVESTIGATIONS, ON A BASIS OF ONE LIGHTNING SEASON'S OPERATION OF ONE ARRESTER

System number	Arrester number	Voltage	Weeks of test	Number of potentiometers	Surges 2.5 times normal or less				Surges 2.6 to 3.5				Surges 3.5 or over				No voltage measurements		
						Discharges				Discharges				Discharges			Discharges		
					Number	250 amps. or less	250 to 500 amps.	500 amps. or over	Number	250 amps. or less	250 to 500 amps.	500 amps. or over	Number	250 amps. or less	250 to 500 amps.	500 amps. or over	250 amps. or less	250 to 500 amps.	500 amps. or over
1	1	140*	22	2	67				1										
	2	120	24	3	210	5	17		28		10		6		2	3			
2	1	66	26	1	58	1	3		13		2	2	6		1	1			
	2	66	26	1	54	1	2		7				7	2	3	2			
3	1	66	11	1	126	2	7		4		2		4		4				
	2	66	11	0													9	20	13
4	1	66	4	1	26				7		7								
	2	66	4	0													0	0	0
5	1	33	23	1	26		2												
	2	33	23	1	32		1		1		1								
6	1	25	5	2	73	5	16	83	5		5		5			5			
	2	25	9	2	26								6			3			

*This is a 140-kv. arrester connected to a 120-kv. system.

voltage. Discharges for surges below this value are unnecessary, and, in some respects, objectionable. This is particularly true for the lower-voltage surges in view of their greater frequency of occurrence.

As shown in Table VII, with few exceptions, the operation of the arresters was satisfactory for surges above 3.5 times normal. Some of these, for which no discharges were recorded, were caused by switching. As switching surges often are not of the same polarity on all three phases, the current discharge path may have been from phase to phase through the neutral interconnection of the arrester units. For such a discharge no indication results on the klydonograph. Again, some surges, over 3.5 times normal, only slightly exceeded this value. In these cases the magnitudes possibly were exaggerated by the limitations of accuracy of the klydonograph. During the tests, only three lightning surges, which undoubtedly were high enough to require a discharge and for which none above the minimum recording point resulted, were recorded.

A considerable number of disharges occurred when the accompanying maximum surge voltages were below 3.5 times normal. This was particularly true on arrester No. 1, system 6 and, to a lesser extent, on arrester No. 2, system 1. In tests where voltage measurements were made on only one or two phases, higher voltages on the other phase or phases likely were responsible for many of the discharges of this type.

The function of lightning arresters, as ordinarily installed, is the protection of station apparatus. They do not necessarily prevent line flashovers. If a high-voltage lightning surge originates at some distance from an arrester, the line insulators may flash over before the surge reaches the arrester. This point is discussed in Part I. To protect against insulator flashovers it would be necessary to distribute arresters at short intervals along a line.

The results of these tests show that the operation of lightning arresters in the field confirms predictions based on laboratory tests. However, the data indicate that the occasions, upon which high-voltage lightning arresters are called upon to operate, are relatively infrequent.

Conclusions

1. Surge voltages due to lightning are unidirectional. The clouds which produce surges are of negative polarity, resulting in positive induced-voltages and negative direct-stroke voltages.

2. The maximum values, reached by lightning surges on transmission lines, are limited by the flashover of the insulators. It is believed that the flashover voltage of 220-kv. transmission line insulation, at the steepnesses of wave front of lightning surges, is comparable to the maximum potentials ordinarily induced by lightning.

3. The flashover voltage of the average insulation of lines up to 140 kv. is about seven times normal for lightning impulses.

4. Seldom more, and often less than two surges, comparable in magnitude to the insulator flashover voltage, appear at a given point of a line during a storm.

5. The frequency of occurrence of the higher surges does not seem to be greater for low-voltage than for high-voltage lines.

6. High-voltage surges are damped below the corona

voltage in traversing a few miles of line. At low magnitudes they may travel long distances.

7. The quantitative measurements with the klydonograph agree with the theories regarding induced voltages and the protection against these afforded by the ground wire.

8. Switching surges occasionally reach six times normal voltage, but 99.2 per cent of all produced are less than 4.5 times normal. Less than 50 per cent of all switching operations create a disturbance.

9. Switching idle lines produces higher surges than similar operations involving load currents. Opening operations result in higher voltages than closing operations.

10. Switching surges usually are unidirectional. When oscillatory, they are highly damped and therefore of short duration.

11. Switching surges are not of serious importance either from the viewpoint of continuity of service or of their effect on apparatus insulation, where the accepted factors of safety for insulation are used.

12. Flashovers and short circuits produce no serious voltage surges where the system neutral is grounded. The nearest approach to sustained high-frequency high-voltage oscillations is the arcing ground on isolated-neutral systems, where this form of disturbance reaches a maximum of about 4.5 times normal voltage.

13. Except for lightning surges, and arcing grounds no high-voltage disturbances, of particular importance to the operating engineer, appear on transmission lines.

14. Nearly 99 per cent of the surges found on cable systems are less than 3.0 times normal voltage. The maximum voltages are of the order of 4.5 times normal; 92 per cent of the total are unidirectional.

15. Where open-wire lines are combined with cables, the surges are somewhat higher than on pure-cable systems.

16. The surges resulting from shortcircuits are *relatively* the most injurious to cables, owing to their longer time of application to insulation, and to their greater energy which results in more of the system insulation being stressed. However, except under certain rare conditions, their magnitude never exceeds 2.5 times normal, and their frequency of occurrence is low.

17. Apparently, transient high voltages are a minor contributory factor to cable-insulation failures.

18. In the investigations of the performance of lightning arresters in actual service, it was found that arresters in general give satisfactory operation, that is, they relieve all surge voltages above the standard test voltages for equipment insulation. Discharge currents up to 2500 amperes occur in practise. From these tests it is concluded that the field performances of arresters confirms predictions based on laboratory tests.

19. Lightning arresters do not protect a line against flashovers at distant points.

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The authors wish to express their appreciation of the excellent co-operation accorded by the various operating companies, upon whose systems these tests were performed. Without this co-operative attitude, such extensive investigations would have been impossible.

RURAL ELECTRIFICATION IN SWEDEN

Rural electrification has developed steadily in Sweden since 1912. The country has no important or extensive deposits of coal or fuel oil, and consequently is entirely dependent on imports for its supply of these commodities. When, at the outbreak of the World War, it became increasingly difficult to import them, the question of making greater use of large available water-power resources naturally became of prime importance.

The high prices received for their produce during the war enabled the Swedish farmers to meet the necessary expenditures involved in the construction and installation work required for the use of electricity on their farms, but during the period of depression following the war, they complained of economic encumbrances, resulting from the building of expensive plants. A noticeable improvement has taken place during recent years, however, and rural electrification is now considered economically profitable.

Approximately one-third of the developed electrical energy of Sweden is controlled by the State and two-thirds by private organizations. It is estimated that the Government's system alone supplies power to about one-third of the rural areas that now have electric service available. When electrifying the rural districts in Sweden, the basic aim has been to supply motor-driven implements with current. Only in a few instances is the current used for lighting purposes exclusively. It is customary, where farms are electrified, to use electric lights not only in the homes, but in the stables, storehouses, granaries, and other outhouses as well.

There has been a large development in the use of electricity for power, and farmers living close together often form "Threshing companies" and buy a large motor. These power units are also used for running stone crushers and sawmills, during the time when no threshing is to be done. Smaller motors are used to operate machines for seed cleaning, chaff cutting, cake crushing, milking, and milk separating. Electric power has not been used extensively for plowing or for irrigation, although considerable interest has been evinced among Swedish agriculturists, who are also interested in it from the standpoint of the preparation of silage, and the drying of grain.—*Commerce Reports.*

Telegraph Traffic Engineering

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THE subject, telegraph traffic engineering, covers a field so wide that to compress it within the limits of a single paper necessitates an arbitrary limitation of the points to be discussed. For this reason there is here presented an outline of only the following four points:

1. Wire layout.
2. Traffic routing.
3. Office layout.
4. Operator assignment.

Wire Layout

As the economic conduct of any business activity is dependent upon a system of adequate, accurate and up-to-date records, so the economic use of a large telegraph wire plant requires a somewhat elaborate scheme for recording the kind and amount of use made of the various facilities as well as for directing changes to be made in such use. The Western Union Telegraph Company has over a million miles (1,600,000 km.) of wire used for the handling of commercial telegrams and for other telegraph company activities. This figure does not include the mileage of wire owned but used by the railroad companies under contracts nor does it include the conductor mileage in underground and aerial cables used in city-wide distribution. This mileage of wire can be divided as to usage, as follows:

Wire used as	Miles of wire	Number of msgs, carried per month
Automatic trunks	266,000	20,100,000
Morse trunks	165,000	4,450,000
Way wires	296,000	3,270,000
Spare and protection	174,000	
Dispatcher and test	30,000	
Other uses	92,000	
	1,023,000	

"Other uses" cover wires in the service of disseminating quotations of stocks and commodities either by Morse or by ticker; wires leased to firms and especially to Press Associations for their use in Morse or automatic service, the so-called "private wires;" and wires given over to some small scattering uses, battery, clock, telephone tie lines, and the like.

In reading the foregoing table one must guard against taking the figures in the right hand column as representing the messages filed with the company by the public. The figures are quoted to indicate the relative density of load on the circuits of different sorts and a given message is counted again each time it is relayed from one circuit to another. That company's report to the Interstate Commerce Commission showed for 1925 a total of 146 million messages filed. It will be noted from the table how vastly more economical is the use of wire in automatic service. There a density of 76 monthly messages per mile of wire is achieved while in Morse trunk service 27 is the prevailing figure and on way wires only 11 can be counted on. Yet over 29 per cent of the whole wire plant is given over to way service, chiefly as the result of adherence to the policy of providing universal telegraph service.

The traffic engineer should be responsible for the amount and general location of wire used and for the economic assignment of circuits to these wires. The material, method of erecting and the detailed location of pole lines and wires are properly the consideration of other departments but these, broadly, must be designed to provide what is required in the way of operating circuits. To this end there must be established a section of the traffic department whose duty it is to maintain a record of wires and of assignment of circuits to those wires, and long experience has shown that it is entirely impractical to maintain such a record unless the same section is given authority to designate the assignment of all wires and to insist that field forces recognize and conform to its orders. This section receives from divisional headquarters in the field suggestions as to improving operating arrangements and itself is continually busy with investigations looking toward improved layouts.

Monthly reports of the volume of traffic handled on each circuit terminating in all important offices are received. These reports show the loads, preferably by half-hourly periods, throughout a typical day and segregate the business into full rate, day letter and night letter traffic. With these data and a knowledge of the practicable operating speeds of various circuits the circuit layout engineer can determine how best to utilize the wires at his command and can justify to that authority which appropriates the money, his requests for additional new wire construction. He daily issues orders in a well defined form, copies of which are sent to every field office which may be interested in the changes. The orders designate changes in circuit assignment together with the date upon which they are to be made effective. These changes are thereupon indicated on the chart of wires which he maintains as his primary record. This chart, with a line for every wire, shows the route followed, all towns being indicated and notations made as to all switchboards at which each wire is cut in either for operation or for test. The material and gage of the wire are shown and at each junction office the cross connections

1. Both of the Western Union Telegraph Company.

Presented at the A. I. E. E. Winter Convention, New York, N. Y., February 7-11, 1927.

are indicated. These latter are customarily in lead pencil in order that alterations may readily be made as orders for circuit layout changes are issued. The chart for the million miles of wire before mentioned is 65 feet (19.8m.) wide and 24 feet (7.3m.) high and, of course, has to be maintained in sections.

In determining upon advisable layouts many facts must be taken into consideration and these vary with the type of circuit involved.

Taking up first the simplest of the circuits, the way wires, we can define as such all circuits that have intermediate offices or "drops" between the terminal stations. Almost invariably they are operated "single Morse," that is by the opening and closing of a circuit in which unidirectional current may flow, though in rare cases where the circuit is very long duplex operation with its greater reliability due to use of current of one polarity for "marking" and of the other polarity for "spacing" is used between the relay office and some repeater point at which a "half-set" connects it to a single Morse wire on which are located all the operating drops.

The volume of business which may be handled on a given way wire is to a considerable extent dependent upon the operating ability of the personnel at the various offices and particularly upon the experience and the judgment of the operator customarily working this wire at the relay office. Then, too, in an effort to give universal service provision must be made for handling business from offices so small that it obviously cannot be in itself profitable. For these reasons the provision of way wires is largely a matter of determining the most economical way to give service under particular conditions rather than a determination of the economy of giving such service. Broadly speaking, it is found that with a number of small offices, say ten or twenty on a way wire, a load of about 150 messages per day is all that is consistent with a satisfactory speed of service. Naturally where distances are great, as particularly in the western part of the country, and the way wires of necessity are very long, a somewhat greater density is enforced before relief is given. An ordinary way wire operated "single Morse" with current supplied generally by motor generators at each end of the line, can comfortably be operated up to about 150 miles (240 km.). Many circuits exceed that length but it is the tendency to so locate relay offices that wires may be shortened to about this figure. The longest way wire in the Western Union plant today is from Denver, Colorado, to Farmington, New Mexico, 497 miles (800 km.), with an intermediate single line repeater at Alamosa. Arrangements are now under way for the installation of equipment at Alamosa to permit relaying at that office this and adjacent way wires, thence handling the business to Denver on an automatic circuit.

If iron wire is used, the possible limit of mileage in a circuit depends upon the amount of deterioration and as the older wires are customarily put into way service it is not unusual to find cases where such circuits run up to 18 ohms per mile (11.2 ohms per km.), though new No. 8 gage iron would measure about 12.5 ohms. Where the abnormal resistance of an iron wire is found to be largely in the joints, conditions may be improved by soldering, brazing or welding as suggested in the paper presented by Mr. Stanley Rhoads (JOURNAL, April 1921). Naturally, the use of No. 9 gage copper, averaging about five ohms per mile (3.1 ohms per km.), improves conditions greatly but insulation plays its part and even with the best of wires it is found that satisfactory service cannot in general be maintained on a way circuit of over 300 miles (480 km.) in length without repeaters.

As the load on a way wire grows, relief may be provided by constructing a new wire from the relay office to a point about midway of the load thus giving room for approximately 100 per cent growth. Quite often, however, the major portion of the load of a congested way wire will be from an individual office in which case the new construction may be placed between that town and the relay office thus establishing a trunk, naturally much underloaded at first, but which, it may be hoped, will gradually grow in usefulness until the day comes when the load justifies duplexing it. Occasionally, as a territory develops, it becomes necessary to establish new relay offices in order to avoid an uneconomical arrangement of many long way wires. The form of an engineering study of the features involved in determining upon the propriety of such a step might alone easily suffice as material for a paper the length of this.

The next general class of wires comprises the Morse operated trunks. With the present development of the printing telegraph, the establishment of new Morse operated trunks is indeed rare except in the manner just above indicated where a way office becomes sufficiently important to have an exclusive wire. Since several printer channels but only one Morse circuit may be put on a wire and, too, since it is easier to secure and quicker to train automatic than Morse personnel, it is not surprising that the duplex Morse trunks are diminishing with the growth of the automatics. The present field for duplex Morse trunks is largely confined to those offices which are maintained in connection with grain, cotton, and other commodity exchanges. In these situations where the messages are short and where the operators are especially selected very substantial loads may be secured. But better loads could be carried by automatics, and we may confidently look forward to the time when, with an improved technique and with customers' prejudices swept away, all important trunks, including those to exchange offices, will be operated automatic.

Broadly speaking when a duplex Morse trunk load grows to over 300 messages each way per day, the limit for a satisfactory speed of service has been reached and it is time to consider measures for relief. Generally it will be found more economical to install automatic

equipment, with its attendant maintenance charges but greater capacity, than to construct new wire. Particularly is this so if the offices involved already have such maintenance in connection with other circuits.

The single Morse trunk, the outgrowth of the way wire as previously described, occupies a wider field. Even here the evidence of trial installations suggests that a single channel printing mechanism of simple structure and substantial operation is, or shortly will be, available with economic advantages over Morse operation so that we may reasonably look forward to the time when manual Morse operation will have disappeared from all towns large enough to warrant a trunk circuit for an outlet and which enjoy 24 hour electric light service to provide the necessary operating power.

A load of 300 messages per day, counting both directions together, is about all a single Morse trunk may be expected to move with a satisfactory speed of service. Relief in general would be secured by duplexing the wire, requiring a more elaborate power plant to supply the two polarities needed by this method.

In taking up the third and most important class of circuits, the "automatic" trunks, it may be well to point out that the word universally used in the industry is somewhat of a misnomer. Really what is meant by "automatic" circuit is a circuit operating printing telegraphs. As a perforator operator does the sending and a receiving operator arranges the blanks in the machine or gums down the tape as the case may be, checks the number of words and calls for the necessary corrections, the only human operation that has in fact been eliminated is the actual typing up on the receiving end. The productiveness of the labor under the two systems is, however, marked. An experienced automatic operator works at between 55 and 60 words per minute while the average output per Morse operator is between 12 and 15 words.

The tendency toward automatic operation on trunk circuits is to be noted, the largest company handling about 80 per cent of its trunk line traffic by this means. In present usage the relation between practical line speeds and customary operator speeds sets a limit of three channels per circuit, these being duplexed so that six messages can be handled simultaneously, three eastbound and three westbound. However, four have been operated in many instances and the indications are that further improvements in the art will result in increasing to at least four and possibly to six channels in the majority of cases. It appears that the average automatic operator can be safely expected to perforate at the rate of 60 words per minute, a word averaging 5 characters and a space. The five unit code used in automatic telegraphy uses $2\frac{1}{2}$ cycles per character so a channel speed of 60 words per minute corresponds exactly to a speed of 15 cycles per second. Therefore a three channel circuit has a line speed of 45 cycles. The present practise indicates that this speed may be maintained on wires up to about 1000 miles and involving probably three repeaters. Longer circuits are operated two channel at line speeds of from 25 to 30 cycles, and such circuits can be and are operated over the greatest distances covered. Specifically, the longest automatic land line circuit regularly operated is one of the New York-San Francisco wires, which is 3779 miles (6100 km.) along the route followed with 13 repeaters located at Washington, Parkersburg, W. Va., Cincinnati, St. Louis, Little Rock, Texarkana, Tex., Dallas, Sweetwater, Tex., El Paso, Tucson, Ariz., Yuma, Ariz., Los Angeles and Fresno, Cal.

In all of these longer automatic circuits at least one and perhaps two of the repeaters are of the rotary regenerative type.

It is possible, by suitable installation of apparatus, to drop off one channel of an automatic at any repeater point, or to intercept one or more channels and work them both ways. Thus the Boston-Cincinnati circuit is equipped for three channel operation one channel working between those cities and two channels cut at Pittsburgh giving Pittsburgh two channels to Boston and two to Cincinnati. Extensive use is made of this ability in situations where the traffic is somewhat lighter than would justify the use of an exclusive wire. For instance, the business of Dayton for New York or of Newark for Chicago would not economically justify a direct wire though ample to support one-third of a wire. So a three channel circuit is set up between Dayton and New York, two channels being cut at Columbus, whose loads happen to fit the situation, giving one Dayton-New York channel, two Dayton-Columbus channels and two Columbus-New York channels. The Newark situation is taken care of by cutting through a channel of one of the Chicago-New York circuits to one on the New York-Newark wire, giving two outlets each way from New York and one through circuit Newark to Chicago.

Perhaps enough has been said under this heading of "wire layout" to give some conception of the involved factors to be taken into consideration in administering the wire plant. With many existing wires on many routes, with varying circuit limitations as to lengths and loads, with alternative possible methods of operation, with different existing and potential relay offices to care for a given territory and with the possibility of combining channel loads on wires in different combinations, it is evident that it is a real problem of economic engineering to properly assign circuits. With a wire plant in commercial service carrying annual charges of perhaps thirty million dollars an improvement of but one per cent in average efficiency would, in an ever growing business, provide a sum of $300,000 per year, enough to pay for a considerable engineering staff to achieve that one per cent saving.

Traffic Routing

When, as elsewhere described, direct trunks have been established between all of the cities whose inter-

change of business either originating or relayed is sufficient to warrant such connection, it is evident that, in general, a number of possible routes will present themselves over which might be handled the business between any two offices which are not directly connected. The economies which can be achieved by judiciously selecting these routes are found greatly to outweigh the cost of the office force at headquarters necessary to determine the facts and to suitably instruct the field. Several considerations affect the choice of these authorized routes; the most important, likewise the most obvious, is that the fewest possible number of relays must be involved. This for the double reason that each relay increases the labor costs and at the same time degrades the speed of service.

Another, and quite important feature, is the relative percentage of full load carried by the various trunk groups involved. For example, a message filed at A and destined to Z, may be handled with one relay through either M or N. Now, the trunks from A to M and from A to N may be equally loaded and both may have ample room for the proposed A–Z message. The operating force at A therefore, unless instructed, might choose either M or N as the outlet. If, however, the trunks from M to Z are already running to capacity while those from N to Z have a wide margin for increase then, obviously, the A–Z message should be routed through N. It has been found that due consideration of this factor may postpone for a considerable period, sometimes several years, the construction of additional wire to relieve congested trunk groups as, for instance, between M and Z in the quoted instance.

A less controlling ground for selection may be the method of operating, because the cost per message is cheaper on the automatic circuits than on the Morse circuits. Lastly, relaying through one office may be cheaper than relaying through another office because the cost per message handling in the first is lower than in the second. This difference may be due to the size of the office, to a more fortunate load factor due to more even fall of traffic throughout the hours of the day, or possibly even to closer operator assignment reflecting a superior grade of management. These differences, however, will be quite small and as a rule the other reasons for selecting a route will have determined the matter before this last mentioned point comes into consideration. It is probably a fact that in a perfectly ideal plant the relay point for business between A and Z should be located geographically half way between those offices. Practically, this thought is given little or no weight in determining routing instructions. It is, however, made a universal practise to route from Z to A through the same relay office as was used from A to Z. A theory was advanced and, in fact, some years ago a slight effort was made toward putting it into effect, that always provided the number of relays was not increased, a message should be routed on its first sending to the office geographically nearest its destination. The idea was that there was more probability of ample facilities and less probability of interruption on all of the available routes between points geographically near together than between points more widely separated. This plan, of course, insures that relayed traffic between A and Z would generally take a different route eastbound from that used westbound. Actually, this scheme is unsound in theory and impractical of application. Under it, it will be found impossible in all or even most cases to keep the eastbound and the westbound loads on a given trunk route equal which is obviously desirable from a wire economy standpoint, else the more heavily loaded side will require the construction of new wire for relief before this relief is needed in the opposite direction. Then, too, so much of the telegraph business is between regular and active customers that the peculiar form and phraseology of their messages becomes more or less familiar to the operating forces who are therefore in a position more accurately and readily to handle them. Evidently, then, to have the eastbound and westbound business between such firms relayed in the same office presents some slight advantage.

Following the considerations set down above the engineer charged with the responsibility of authorizing routes from each point to every other point in the country can readily reach his conclusions on the basis of the records of direct trunks and of their loads which have already been described. Then there remains the matter of issuing instructions to the field.

The earliest route guides consisted merely of a list of the telegraph offices, a separate list for each state, with a statement after each entry of the office which acted as relay for it. The inadequacy of such an arrangement is evident, for the card would show that Gorman, Md., was relayed by Pittsburgh while the office at Billings, Mont., would be wholly uninformed thereby as to whether to send the message to Helena, Denver, or Minneapolis, his only three outlets. Then, in the larger offices, the local forces made up route guides of their own, taking as a basis the "tariff book," which is the telegraph directory, and lists all the telegraph offices by states, entering the name of the relay point to which they should send messages for each of the listed destinations. This was faulty because decision as to route lay with the local people whose knowledge of the conditions was not complete and also it offered a very unsatisfactory arrangement for ease of consultation.

The most modern method, which has some five years' experience to justify it, consists of issuing from the home office in New York routing instructions for every office of sufficient size to warrant three or more trunk outlets. These instructions are in the form of lists printed on narrow slips much the size and shape of a newspaper column which can be slid into suitably designed metal leaves mounted on the wall or on racks in the operating

rooms. Several duplicate copies may be displayed if necessary. They are prepared specifically for the office in which they are used and they tell the local forces what they are to do with each message rather than what happens to the message at points beyond their reach. That is to say, if the route clerk at Billings has a message addressed to Gorman, Md., on one of these instruction sheets headed "Maryland" he finds the entry "Gorman" and after it the direction, "Minneapolis." The Billings operator then sends the message to Minneapolis and has no further interest in how it is routed.

In the Western Union system there are 87 offices at which such route guides are displayed. The tariff book lists 65,000 names of places in the United States. Not all names are listed in any one guide, for about three-quarters are eliminated by the expedient of determining for each state which outlet covers the greatest number of places, then listing only the other places with the direction that those not listed be routed to that outlet. For instance, most Maryland points are relayed at Philadelphia, Baltimore or Washington, all of which cities are best reached from Billings through Denver but fifteen towns, including Gorman, are relayed by Pittsburgh which has a direct trunk to Minneapolis. Therefore Billings' route guide for Maryland consists of a statement that all points go to Denver except the list of names that go to Minneapolis. So, though Maryland has 1400 listed offices, the Billings guide carries but fifteen of them.

To prepare these instruction lists a somewhat elaborate organization is employed. Linotype slugs are made for each entry on a linotype machine in the executive offices at headquarters and these are held in galleys especially shaped, the galleys being filed in metal racks also designed for the purpose. Changes are continually being made and when any change is made either in trunk routes or by reason of new offices being added to the list, such changes are made up on slugs which are put in the galley in lieu of or in addition to those already there and as many copies are struck off as may be necessary. These are made on a proof press which is the most satisfactory way of taking a few copies from type slugs carried in galleys rather than in chases. These instruction slips are then mailed to the respective offices. A record is kept of them and it is required that the receiving office remove the slips which they are to replace and mail the old slips back to New York. This not only serves as a receipt for the new slips but is almost certain evidence that the local forces have not erroneously removed a perfectly good slip and put the new slip which really belongs elsewhere, into its place.

A considerable office force is needed to effect this procedure. The benefits realized are those of more efficient use of wire plant, reduced number of relays and improved speed of service due to elimination of misroutes. While it is difficult if not impossible to prove the monetary saving, it seems beyond question an advisable expenditure to those who have had an opportunity to compare the routing of business before the advent of this method with that of the present time. Since all the linotype slugs for all of the instructions for all of the offices are kept permanently on file in order that reprints may readily be made when changes in individual items occur, it is obvious that a considerable amount of type metal is involved. For the 87 offices mentioned, a total of about 1.3 million names are carried involving some 45 tons (41,000 kg.) of type metal.

Some provision must, of course, be made for routing over unusual channels when confronted by unusual conditions. A telegraph company has always to contend with inoperative circuits due to wire troubles; sometimes more, sometimes less, but always in some part of the country to such a degree as to exceed the possibility of restoration by spare wires paralleling those interrupted. Then, too, extraordinary files of traffic occur which when scheduled for a trunk group of limited carrying capacity may well overload it. To take care of these two classes of emergencies, those of wire failure and those of extraordinary file, a department is maintained centering in New York with branches in several of the important telegraph centers, known as the Dispatching Bureau.

The Dispatching Bureau is the only authority recognized as supervening over the authorized routing instructions. The Dispatching Bureaus are equipped with wires picking up all of the more important centers of the country and used solely for dispatcher circuits. A dispatcher is hourly advised of the traffic conditions of each of the important offices in his territory. He is advised both as to the number of messages on hand and the filing time of the oldest. He is also informed of all circuit failures which it has not been possible to make good with spare paralleling facilities. With this information at hand he is in a position to and he does instruct the offices as to temporary routings to reduce congestion which may have arisen. Having knowledge of the conditions on all groups he is able to avoid the earlier unfortunate practise of having the office A send on the N trunk business destined to Z and authorized to go to M, because his M trunk was overloaded or in trouble when at that particular time the N-Z trunk, unknown to him, was already badly congested or out of service. The dispatcher is also authorized to divert a wire from one assignment to another assignment even though it leaves the first assignment short. This is a function which cannot safely be left to the local forces because of their natural ambition to keep their own offices clear even at the expense of taking down a long through wire to make good a short local wire. The installation of the Dispatching Bureaus has proven of great benefit in expediting the movement of traffic under abnormal conditions and of increasing the useful distribution of wire when storm conditions prevail.

Office Layout

If we are to separate the engineering of a telegraph company into various parts among which are traffic engineering and fundamental plan engineering, we find that the matter of determining operating room layouts falls within both of these classifications. Practically, it works out that in the larger offices being newly established and planned for continuing service through a relatively long period of years, that part of the en-engineering force which has to do with the estimates of future growth and fundamental plans undertakes a major part of the office planning. Even in this case, however, the details of the initial equipment are arranged by, or at least are approved by, those specifically responsible for the traffic engineering.

Prior to the general use of printing telegraphs we had the "quad room," so-called, which really more often was merely one end of the operating room, in which were located the duplex repeating sets, the duplex terminal sets, the quadruplex sets, such repeaters as there might be, together with the main switchboard and the loop board. Now, with the high proportion of printing telegraph circuits, the so-called "automatics," this older arrangement has been departed from in a measure. In a large modern office we have a terminal room, usually on a floor separate from the operating room, in which are located the main and loop switchboards, the repeaters, both relay and rotary, and the Morse terminal equipment, whether single, duplex or quadruplex. The terminal apparatus for the automatic circuits including the main line relay and the duplexing equipment in general present practise, are carried to the operating room floor and respectively located on the distributor tables appurtenant to each automatic circuit. These distributor tables are set at the head of the line of alternate sending and receiving positions making up the two or three channels worked on that circuit and while other arrangements might be possible, the desirability of this layout is so great that the floor plan of the operating room is customarily forced to conform to this arrangement. The Morse operating positions, either single or duplex, and carrying only local circuits from the quad room, present an easier problem and may be placed around the room as conditions permit although, of course, for the best handling of physical messages within the office, proper grouping is desirable.

In the normal operating room we would expect to find the following sections:

a. Automatic trunks
b. Morse trunks
c. Way Wires
d. City lines
e. Tube center
f. Routing center

The equipment for recording and delivering to customers over the public telephone and for operating the telephone circuits to branch offices which are so served, is usually in a "phone room" separate from but near to the operating room and connected therewith by some type of message conveyor, either belts, tubes, Lamson carriers or gravity chutes.

As previously suggested the automatics will all be arranged in rows. At the head of the row is the distributor table with the artificial line for duplexing, the main line relay, the phonic wheel motor and the tuning fork that drives it, coupled to the rotating brushes and the segmented face plate which constitutes the distributor, and sundry miscellaneous apparatus. Then in line come the tables at which sit the four or six operators needed to man the two or three channels, all facing in the same direction. These are invariably arranged in alternating perforating and printing positions, in such order that the *A* channel perforator is to the right of the *A* channel printer. Two such rows are placed back to back with a "pickup" belt between. These belts, open on top and continuously moving, take the received messages as they are removed from the printer (or from the gumming desk if the position is equipped with the newer tape printer rather than the older page printer) and carry them to the ends of the rows where other mechanical conveyers take them to the routing center. An aisle is left between parallel rows as near to 5 feet 6 inches in width as the floor plan of the building permits.

The Morse positions are also aligned in a similar manner though their arrangement is much more flexible as the only limitation as to adjacency is that for duplex operation the sending position be immediately to the left of the receiving position. Quite generally a pair of duplex positions are so equipped that they can be used to table two single Morse wires. These rows, like the automatics, are arranged back to back and have a pickup belt between them.

In handling commercial business on way wires it is not the custom for way offices even on the same way wire to handle messages directly one to the other, partly because railroad operators generally have other duties and it is easier for one to unload his traffic on the main office which is always there rather than to try to raise the man at the other small office; partly too, because a main office relay copy is desired for check control to protect the company's revenues.

An experienced main office operator covering a way wire will become familiar with the train schedules, meal hours, and other facts regarding the offices and the operators with whom he works and he can turn this knowledge to good advantage with considerable conservation of line time when he is trying to dispose of business to these points. Evidently it is not conducive to economy to spend many minutes calling on a wire to raise an office which is closed for lunch or where the operator is out arranging baggage to put aboard an approaching train.

Improved operating efficiency at the main office on way wires is achieved through the use of "concentrator

units" a device which is nothing more nor less than a small switchboard in which the line terminates and on which a lamp lights if a prearranged code is sent on the wire by any of the outer offices. These outer offices may communicate with each other or with, in many cases, the head railroad office, without calling in the telegraph company's main office operator. The concentrator units are so situated that four operators, two on each side of the table, may at any time reach any of the eight lines terminated in the concentrator by plugging into the jack associated with the corresponding signal lamp, jacks and lamps being multipled on the two sides of the unit. Arrangements are also provided, either in the loop board or immediately adjacent to the concentrator unit, whereby any given line can be taken out and tabled individually during the busy hours of the day if the load during those hours warrants the entire attention of one operator.

It is still the general practise to run "number sheets" on all circuits which is to say that between the main office and each office on the line a series of numbers is run and after the transmitting of each message one of these numbers is crossed off at both the main office and the distant office. These series of numbers appurtenant to any one wire are in general kept upon a single number sheet. The message itself bears the same number. At the end of the day the numbers are compared between offices and the whole is intended to guard against lost messages. Were it not for these number sheets obvious economies could be secured by terminating all of the way wires in one switchboard, multipled if necessary, and handling the traffic very much as calls are handled on a telephone switchboard, but the impracticability of moving the number sheets around between the various operators involved, according to present practise, limits the concentration to units as before described. Upon these units a simple rack is used to hold the number sheets belonging to the wires terminating therein and the operator who for the moment is working with an office on a specific wire reaches for and puts before him the number sheet of that wire and makes the necessary notation thereon.

Of course not all way wires are in concentrators and some are put in concentrators during slack hours but given individual positions during busy hours. The arrangement of these Morse positions in the room does not differ from that of the Morse trunks.

The "city lines" are the short single Morse wires to branch offices throughout the city. They are worked on positions quite the same as the way wires.

The growth of these various methods of reaching branch offices is interesting. Originally, of course, Morse was used entirely but beginning some fifteen years ago, the telephone was introduced. Its advantage lay partly in the fact that it is faster than Morse even when all proper names and questionable words are spelled out, "S for Sugar, M for Mary, I for Ida, T for Thomas, H for Henry, Smith," etc., and the message then repeated back. Even more advantage resulted from the greatly widened field from which branch office personnel could be selected, an important consideration in view of the fact that quite generally besides transmitting messages, they have to meet the public, keep accounts and generally represent the company. For all the substitutions of phone for Morse on city lines and automatics on the trunks it is nevertheless true that the number of available operators for manning the remaining Morse wires is decreasing chiefly because of the failure of the younger generation to learn the code and enter into this profession.

In their turn the telephone city office lines are now giving way to the short line printer because of the somewhat greater accuracy and the considerably greater output which may be achieved by this means.

Pneumatic tubes have been used for moving messages between main and branch offices for many years. Roughly, a speed of 1000 feet per minute may be expected and not more than a five minute run may be allowed without unwarrantably degrading the speed of service. From this it follows that in general, branch offices cannot be served by tube if more than a mile from the main office. The installation costs of tubes are quite high but their operating costs are extremely low as compared with any other method. For that reason great savings can be made by means of tubes in an office with a sufficient number of messages per day depending upon the distance and upon other conditions. After tubes have once been installed, then growths of several hundred per cent can be taken care of without any appreciable increase in cost. In general it is found economical to use tubes to offices where the loads are in excess of from two hundred to six hundred messages both ways per day.

It is beyond the scope of the present paper to describe the methods used in moving messages from one part of the operating room to another as is necessary in connection with the relay and delivering functions. Suffice it to say that for this intra-office routing it is found, in general, best to pick up business of all sorts from the incoming wires and carry it automatically to a single "route center" located as near the center of the operating room as conditions will allow. At the route center a slow moving belt carries the business before the requisite number of route clerks who dispatch it to the "drops" nearest the proper outgoing wires. Largely this is done by belt conveyers but sometimes the route clerks lodge the business in pigeon holes whence it is taken by "routing aides" by hand to the outgoing wire or perhaps it is dispatched by Lamson carrier or by tube. In any case "routing aides" move the messages from the "drops" to the outgoing operator positions.

The pneumatic tubes are grouped at a "tube center" generally immediately adjacent to the route center. Where the number of tubes warrants, instead of having the clerk who inserts the carriers into the tubes load the messages into the carriers, the carriers are all loaded at

one location and distributed to the tube heads by a conveyer belt. The carriers being variously colored, the tube attendants readily insert them into the proper tubes. On very busy tubes an automatic device is employed which insures that successive carriers are not despatched in less than the permissible time interval and yet conserves tube capacity by assuring that when business is on hand it is sent just as promptly as is consistent with proper carrier speed in the tubes. According to the fall of traffic one or several messages may be enclosed in a single carrier. The tubes are 2¼ inches in diameter, the carriers of course less, and good practise indicates that not more than a dozen messages should be inserted in a single carrier.

The matter of delivering telegrams direct to the patron and receiving them direct from him over a public telephone system presents many angles. The success of a widespread application of this method depends of course upon the attitude the public takes toward it. This attitude in turn may be affected both by the physical conditions and by the development work carried on by the telegraph company's publicity forces. For instance, in a manufacturing town where the telegraphing is largely conducted by the offices of the mills and the mills themselves are naturally scattered at some distance from the center of the town, the telephone pickup and delivery is looked upon with considerable favor. In other districts where branch offices are located within a few steps of all of the biggest users, considerable resistance is felt toward an effort to make telephone deliveries. There is no question that telephone delivery direct to the customer is more expeditious than branch office and messenger boy handling and since speed is practically the sole incentive for using the telegraph, the telephone seems to be the logical method of effecting delivery and the public prejudice against it can, in large measure, be attributed simply to habit, and can be overcome to some extent by proper publicity work. As extremes of these conditions might be pointed out, on the one hand, the city of New Haven, Connecticut, where 55 per cent of all telegraph deliveries are made over the public telephone and on the other hand Manhattan Island where no effort is made to deliver by telephone any telegrams to addresses south of 59th Street.

Operator Assignment

Operator assignment studies are predicated to such a considerable extent upon certain fundamental facts regarding telegraph traffic that an outline of these features seems to be essential to an understanding of this problem.

After a message is filed at a branch office a certain amount of time is required to complete the primary record concerning this message before it can be sent to an operating position for transmission. Similarly, when a message is received at the main office on any circuit and this message is destined for retransmission by the main office to another office a certain amount of time is required to get this message through the distributing center and deliver it at the proper sending position. This time interval is known as the "office drag" and is a variable depending upon the size and type of the office.

When a message arrives at a given circuit for transmission to the distant terminal, other messages may be on hand awaiting transmission. All the traffic for this circuit is then sorted by classes in filing time order, the earliest full rate message being transmitted first.

The message last received will therefore be subject to some delay before it is transmitted and a decision as to how long it may be so delayed before it is transmitted is in order. If we assume as permissible an average delay of not more than five minutes we may find that with the given load one operator can handle all the traffic within the time limit. On the other hand, if the average delay is fixed at one minute it may be necessary to use no less than four sendings to handle the same volume of traffic.

The latter figure will obviously result in a tremendous increase in the cost of handling this traffic and in determining the time limits within which all traffic must be transmitted after it is received in an office, the company's policy must be based on the relation between the cost of the desired speed of service and its value to the patron, as reflected in the volume of traffic which may be expected as a result of this speed of service.

Having decided upon the average and the maximum delay to be maintained we may now proceed to develop the load which we may reasonably expect an operator to handle. At this point we find that if an operator working on a single channel between two offices is given such an amount of traffic as will cause her to work more than 43 minutes out of an hour, the desired speed of service cannot be maintained and it becomes necessary to cover a second sending position.

As the load increases the second operator absorbs more and more of the excess and we find that we can still maintain the speed of service up to the point where each of the two operators is busy for 52 minutes out of the hour. Assuming a channel capacity of 60 messages per hour we can expect to handle 43 messages per hour on a single channel to a given office but when two channels are in use to this office up to 52 messages per hour can be transmitted on each channel without degrading the speed of service.

This increase in available work time per operator continues as the number of operators in the group increases up to the point where 10 channels are in use, when approximately 100 per cent of the operators' time is usefully employed and each channel is working at the full capacity of the apparatus. As automatic trunk groups are largely of two or three channels one cannot normally expect to get 100 per cent capacity from the equipment even during the busy hour. It is only in such large groups as the Chicago-New York

circuits where fourteen duplex channels are provided that the capacity of the equipment and the time of the operators is fully utilized. In times of stress, of course, by arbitrarily degrading the speed of service through increasing the time limits, the available operator work time is increased to such an extent as to clear up abnormal accumulations of traffic without increasing the operator staff.

Further limits are placed on the amount of traffic which can be handled over a given channel or channels, by the safe operating speed at which the circuit can be worked. By safe operating speed is meant a speed which can be maintained day by day without introducing too many errors or interruptions.

Detailed analysis of the circuit load reports which record the volume of traffic filed for transmission on each circuit or circuit group during each half hour of the day, shows that not only are there wide fluctuations in the amount of traffic to be handled in any half hour period, but there are variations due to the day of the week as well as seasonal changes. Estimates of the traffic to be handled tomorrow or next week, and the operator requirements based on this traffic must of necessity recognize these variations.

Analysis of the actual messages flowing regularly over a given circuit shows that the number of characters in the average message is practically a fixed quantity for each class of traffic handled on the circuit, but this average length is not the same for all circuits.

Having decided upon the operating speed of the circuit in words per minute and knowing the average length of the message to be handled on it the theoretical capacity of the channel in messages per hour can easily be determined. From this theoretical capacity we must deduct allowances for

a. Lost channel time due to temporary wire and equipment failures.

b. Operating or apparatus errors which necessitate the correction of messages which have already been transmitted.

c. Errors which the operator is conscious of having made and corrects before the complete message is transmitted.

When these deductions have been made it is possible to state that under the given conditions a certain number of channels must be manned to handle the estimated volume of traffic.

It will be noted that up to this point we have apparently assumed that the operators can work at any circuit speed. The fact is that while Morse and phone operators are in general limited only by their ability and not by the circuit characteristics, the automatic operator is limited by the speed at which the channel operates. Several thousand stop watch observations on perforator operators indicate that the present maximum operating speed of 65 words per minute on automatic circuits is not only well within the range of the average operator but that this rate can be sustained without undue fatigue.

In actual operating room practise, it has been found desirable to locate all the trunk circuits in one group, all city circuits in a second group with a third comprising

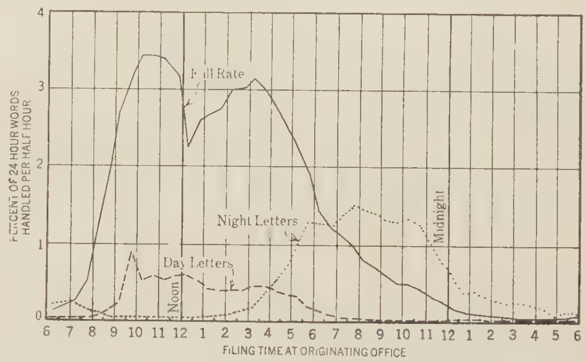

Fig. 1—Load Curve—Entire Telegraph Plant

the way circuits. Interchange of operators from one position to another within the given group is facilitated by a further division of the three major groups into

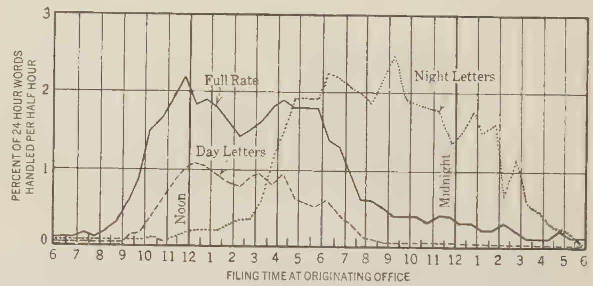

Fig. 2—Load Curve—Atlantic Coast to Pacific Coast

automatic, Morse and telephone operating sections, and the operating staff is in general assigned by methods.

An operator's tour of duty is nominally eight hours,

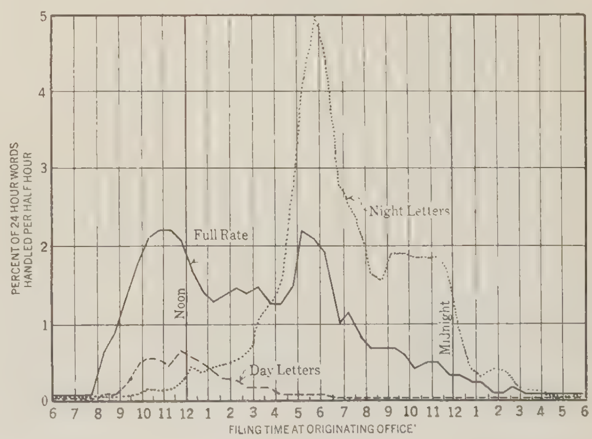

Fig. 3—Load Curve—Pacific Coast to Atlantic Coast

but as each operator receives a fifteen minute rest period after she has been at work approximately two hours, and a second fifteen minute period about midway of the last four hour working period, both of which

are on company time, their actual working period, is only 7.5 hours. Advantage is taken of the relief periods to minimize the effect of fatigue, particularly on the automatic circuits by alternating the kind of work. If an operator begins her tour of duty at a sending position she will be assigned to a receiving position after the first relief period. Upon her return from the lunch relief she will again be assigned to a sending position.

Reference to the load curve for the entire telegraph plant shows that while the traffic is heaviest during ordinary business hours, *i. e.*, 9:00 a. m. to 5:00 p. m., there is a considerable volume remaining to be handled up to 10:00 and 11:00 p. m. and the beginning of any operator's tour of duty is naturally determined by the shape of the load curve on each individual circuit.

As examples of extreme deviation from the average are given graphs of the eastbound and the westbound file of business between cities respectively on the Atlantic coast and the Pacific coast where the difference in standard times and the greater absolute savings to the patron make the use of the deferred services more extensive.

While the shape and position of this load curve is generally the same for a given circuit minor variations occur which serve to set these peaks ahead or behind the normal time position. Our obligation to give service requires us to anticipate these changes and the positions are covered in advance of the time when the change in load is expected to occur.

With the information already available it is a relatively simple matter to assign the operators in such a way as to provide for handling the full-rate traffic filed during the business day. Ordinarily, additional staff would not be assigned during the day hours to handle deferred traffic because the staff needed for full-rate traffic has sufficient idle time available to permit of handling the deferred traffic during these idle periods if the transmission of the deferred file is sufficiently delayed. Naturally we cannot delay this traffic to such an extent as will prevent the delivery of these messages before the close of the ordinary business day but in general this does not occur.

During the latter part of the afternoon and evening we are confronted with a falling load but as it is necessary to bring on a certain number of operators at this time to replace those whose tour of duty has just been completed and as it is manifestly unfair to release them without an opportunity for a full day's work, the falling full-rate file is supplemented by the night letter file in such a way as to keep this staff busy until after midnight when only a few operators are required to handle the balance of the file.

A complete assignment of the staff required for the entire 24 hours may now be made for each of the circuits or circuit groups. The total number of operators required to handle the traffic on all circuits including relief operators may then be determined and to this total is added a sufficient number to provide for operators who are either late, or fail to report, those on vacations, etc.

Roughly, and subject to considerable variation, in specific instances, the total number of operators needed in an office to conduct operations throughout the 24 hours, to cover vacation and sickness reliefs, absentees and those tardy, can be taken as 2.8 times the number of operating positions covered during the busiest half hour of the day.

PURE VANADIUM PRODUCED

At a meeting of the American Chemical Society at Richmond, Va., last month, the production of pure vanadium was announced by J. W. Marden and M. N. Rich, research scientists of the Westinghouse Lamp Company.

Vanadium has been known in its compounds for a long time, but in spite of a century of efforts on the part of chemists, no one has previously been able to produce it in its pure form. The method employed by the authors is to heat a mixture of vanadic oxide, metallic calcium, and calcium chloride in an electric furnace for an hour, at a temperature of 900 degrees centigrade. After cooling and stirring the resulting mass in cold water, metallic vanadium is obtained in the form of beads, which "are very bright, and quite malleable," said the authors. "So far as analysis can determine, they are 99.9 per cent pure metal.

"The density of vanadium is 6, and melting point approximately 1700 degrees centigrade. It is one of the least volatile of metals at its melting point."

THE LARGEST DIESEL GENERATOR

In the annual report published in the October 1926 issue of the Institute's JOURNAL our readers were informed that the mentioned Diesel generator of a capacity of 3175 kv-a. at 25 cycles and 125 rev. per. min. was, at present, the largest machine of its kind driven by a Diesel motor. Messrs. Siemens-Schuckert of Berlin-Siemensstadt now inform us that they have constructed much larger generators to be driven by Diesel engines. The largest Diesel set was put into service last year by the Hamburgische Elektrizitatswerke A.-G., of Neuhof, near Hamburg (Germany). A 15,000-h. p., 9-cylinder, Diesel motor, constructed by Messrs. Blohm & Voss, of Hamburg, in cooperation with the Maschinenfabrik Augsburg-Nurnberg, drives the largest three-phase generator of this kind. This was supplied by Messrs. Siemens-Schuckert and has a rated output of 13,000 kv-a. at 94 rev. per min. and 6300 volts. The set may be brought from a cold state to its full rated capacity within eight minutes. Full information regarding it is contained in the German *Siemens-Zeitschrift*, issue of January 1927 and in No. 3, (March issue) of the British *Siemens-Schuckert Review*. It will also appear later on in the Spanish *Revista Siemens*.

Abridgment of

The Synchronous Converter

Theory and Calculations

BY T. T. HAMBLETON[1] and L. V. BEWLEY[1]

Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*The first part of this paper is devoted to the purpose of presenting a clear conception of the internal voltages, currents, heating, and armature reactions as related to the physical structure of the simplest converter and as related to the passage of time. These may be styled "space" and "time" relations. "Space" relations are indicated by means of diagrams representing as nearly as possible the physical structure of the converter. "Time" relations are shown by conventional curves and vectors.*

The accepted mathematical expressions for voltage ratios, heating effect of currents, and armature reaction imply that certain facts be disregarded. This is done in order to simplify their development.

The mathematical treatment developed in the appendixes to this paper includes most of these disregarded factors and makes it possible to evaluate them.

This treatment is based on the method of "harmonic analysis" by which any regularly repeating function may be represented.

THE genera theory of the synchronous converter has been given less attention in the technical press than has that of the more widely used purely alternating-current machines. Moreover the synchronous converter has been treated in less detail in our technical colleges and engineering schools. It seems therefore that the engineering fraternity in general may not have as clear a conception of phenomena taking place in the converter as in the other types of electrical machines.

It is the purpose of this paper, first, to present a clear and simple explanation of the internal actions and reactions of the synchronous converter without resorting to laborious mathematics; and second, to set forth for those who wi'l be interested the complete mathematical treatment by harmonic analysis.

The subject divides naturally into three parts:

Voltage Relations

Heating Effect of Current

Magnetomotive Force Relations.

Voltage Relations

The ratio of effective a-c. voltage for any number of phases may be determined by representing the voltage of each armature coil vectorially as in Fig. 1 where the voltage of the complete armature is represented by a regular polygon of vectors which is so related to the two field poles that the magnitude of the voltage of any coil or any phase is measured by the projection of the vector or vectors upon the axis $(y - y)$ which lies at right angles to the axis of the po'es. This axis is usually called the "quadrature axis."

This combination vector diagram and pole drawing is in accord with the physical facts, in that maximum instantaneous voltage is indicated for a given vector (such as c) when it is directly under the center of a pole. Likewise the maximum voltage is generated in a coil when its sides are pass:ng under the center of a pole.

It is evident that the maximum instantaneous voltage across any diameter $(A\ B)$ occurs when that diameter coincides with the "quadrature axis" which is also the brush or neutral axis. Hence the d-c. voltage at the commutator is numerically equal to the maximum instantaneous voltage of an a-c. diameter, and the ratio of effective a-c. diametral voltage to d-c. is the

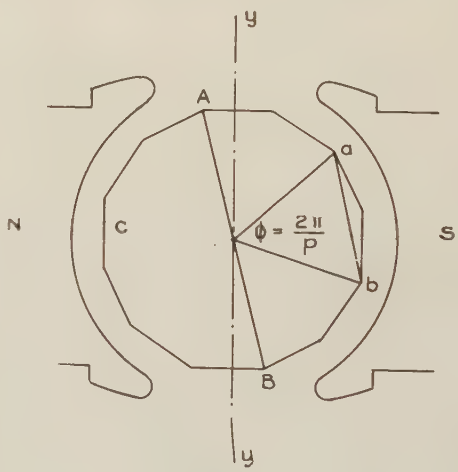

Fig. 1

ratio the effective value to the maximum value of the a-c. wave. This ratio is $\frac{1}{\sqrt{2}}$ or 0.707 for the ideal condition of 100 per cent efficiency and a pure fundamental sinusoidal a-c. voltage.

If the converter has p phases per pair of poles, then each phase covers an angle $\phi = 2\,\pi/p$, and the cord $a\,b$ subtended by this angle is a measure, under ideal conditions, of the maximum a-c. voltage induced in the phase. It is easily seen from the geometry of Fig. 1 that the ratio of the d-c. voltage $A\ B$ to the maximum a-c. phase voltage $a\,b$ is

$$\frac{A\,B}{2\,(A\,B/2)\sin\phi/2} = \frac{1}{\sin\pi/p}$$

or in terms of the effective value of the a-c. voltage it is

1. Both of the General Electric Co., Schenectady, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

$\sqrt{2}$ sin (π p); so that the normal voltage ratio of a synchronous converter is primarily fixed by the number of phases p. It is well to point out, however, that this result has been arrived at by assuming a sinusoidally distributed field flux passing through zero at infinitely thin brushes; an infinitely distributed ring or full pitch drum winding; zero armature reaction; zero armature impedance; and a magnetic circuit of constant reluctance for all positions of the armature.

These ideal conditions are almost never realized in commercial machines because of practical limitations, some of which will be discussed.

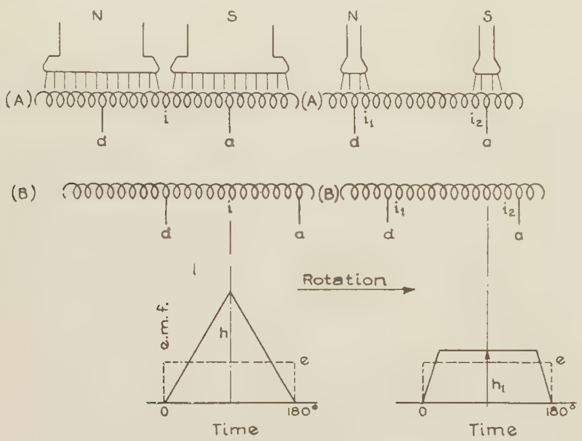

FIG. 2

The necessity of providing a neutral zone for commutation and the space requirements of the field coils both demand a shorter pole arc than corresponds to a sinusoidal distribution of the flux. The result is a slightly flattened a-c. voltage wave which has a higher ratio of effective to maximum; the latter always being equal to the d-c. voltage. It will be found that the majority of commutating pole converters have a no load diametral ratio of approximately 0.725 and, due principally to resistance losses, a full load ratio of 0.74 to 0.75.

The effect upon wave shape of varying the pole face arc can be made plain by considering two extreme cases shown in Fig. 2.

Here is represented poles having an arc of 180 deg. and others, a very short arc. It is assumed that the flux density is constant across each pole face and of such value that the same effective a-c. voltage is generated across a diameter of the armature winding.

It is evident that the diametral phase of winding $d\ i\ a$ in position A under the long arc poles has equal and opposite voltages generated in the two halves $d\ i$ and $i\ a$ so that the total voltage is zero. Now equal voltages are generated in all conductors and the number of conductors under each pole vary directly with time and position of the phase in space and therefore the total voltage of the phase $d\ i\ a$ will be a straight line function of time and space position as shown. The maximum e. m. f., h is generated when the phase is central with the pole S, position B. The effective a-c. value of this voltage is e and the maximum or d-c. is h which appears continuously between two fixed points between the pole tips where brushes may bear on a commutator connected to the winding.

Now similarly under the short arc poles equal and opposite voltages are generated in $d\ i_1$ and $i_2\ a$ in position A and the resultant voltage is zero. When the phase has moved the distance $d\ i_1$ coils in it will be under the influence only of pole S and the total voltage between d, a will be constant until the tap d reaches the pole S. The net voltage of this diametral phase will be trapezoidal, as shown, with a maximum value h' and the same effective value e as in the previous case.

Thus the effect of increasing the pole arc, keeping the same effective value of a-c. voltage, is greatly to increase the d-c. voltage; and vice versa.

The regulating pole converter uses this principle for varying the d-c. voltage with constant effective a-c. voltage impressed. A variation of the net pole arc

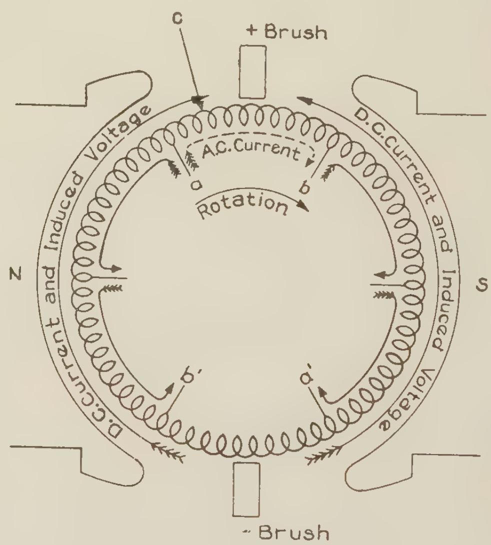

FIG. 3

is secured by constructing each pole and pole face in two adjacent parts one larger "main pole" and one smaller "split" or "regulating" pole. The exciting field of the latter may be varied, or even reversed, which results in a net effect equivalent to varying the total pole arc.

Heating Effect of Armature Current

Before considering the explanation of armature heating, it is advisable to mention the fundamental definition of "motor" and "generator" action.

Generator action in any dynamo-electric machine is the act of current flowing through it in the same direction as, and by means of, the internal "induced" e. m. f.

Motor action in any dynamo-electric machine is the act of current flowing through it in the opposite direction to the internal "induced," and by means of an external impressed e. m. f.

In the converter it is convenient to regard the direct current as due to generator action, and the alternating current as due to motor action. The actual current in any conductor results from superposition of these two.

A bipolar converter, having for convenience a Gramme ring armature winding, is represented in Fig. 3: The mechanical rotation of the armature is clockwise. Zero time is selected as the instant when the center of the phase *a b* coincides with the center line of the brush.

The voltage generated under each pole in the conductors passing under it is directed from the negative

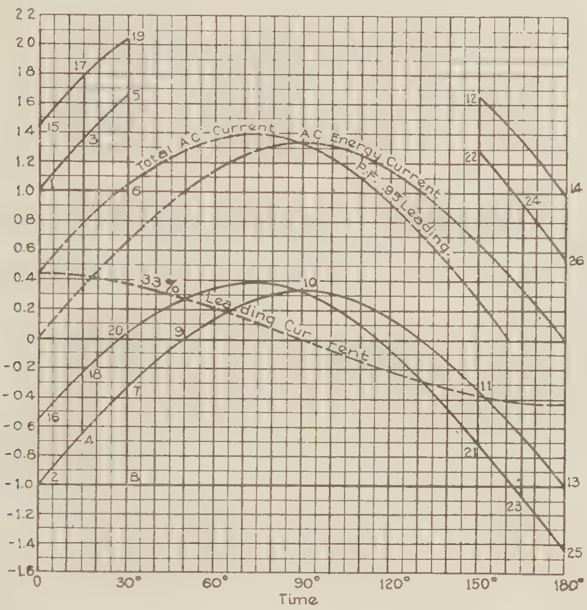

Fig. 4

brush toward the positive brush through both of the armature circuits.

The specific case of a six phase converter is assumed, where the phase *a b* occupies 60 electrical degrees.

With the phase in the position of zero voltage, corresponding to zero time in Fig. 4, there is no alternating current at unity power factor. But when the phase moves toward the pole *S* the voltage will be induced in the direction from the tap *b* toward *a*.

Now the a-c. motor, or input current, must flow from *a* to *b* in opposition to this induced voltage. At the same time the d-c. generator current is flowing from *a* to the positive brush in the same direction as that in which the alternating current is just starting to flow and the two currents are added. This condition holds true in any part of the trailing half of the phase which has not yet passed under the brush.

The magnitudes and relations of these currents in time are shown in Fig. 4. The direct current, taken as unity, is represented by the line 1, 6, 8, 13 for the tap coil *a* which is commutated at point 6 after the 30 deg. of time required for *a* to rotate to the brush.

The alternating current (dotted curve), since it flows in the same direction, adds to the direct current in coils not yet commutated; hence, the current curve of the tap coil *a* is 1, 3, 5 (commutates), 6, 7, 9, 10, 11, 13.

The heating effect of this current is proportional to its square as shown in the corresponding Fig. 5 by the similarly numbered curve 1, 3, 5, 6, 7, 9, 10, 11, 13. The total or integrated heating is represented by the area under this curve.

In like manner the current in coil *c* half way between *a* and the phase center may be traced. This coil will commutate after 15 deg. of time. The current is 1, 3 (commutates), 4, 7, 10, 11, 13, Fig. 4, and the heating similarly numbered in Fig. 5.

The current and heating of the center coil which commutates at zero time is similarly 1, 2, 4, 7, 9, 10, 11, 13.

The current and heating of tap coil *b* may be traced through in the same manner. The direct current which has already been commutated flows in the opposite direction to the alternating current for 150 deg. of time required for the tap to rotate to the negative brush. The total current follows 2, 4, 7, 9, 10, 11, commutates, and follows 12, 14. One-half cycle or 180 deg. of time then finds tap *b* at *b'* Fig. 3. It is evident that this current cycle is the exact equivalent of that shown for

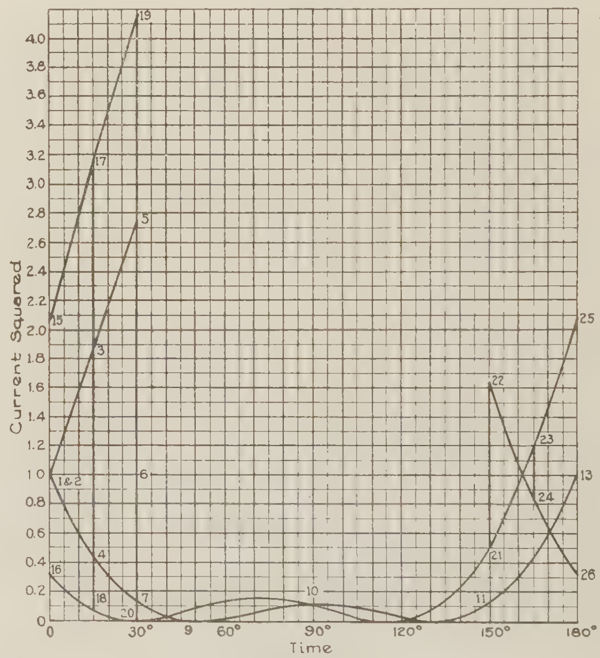

Fig. 5

tap coil *a*; similarly, it is evident that any two coils equidistant from the center of the phase are subject to the same heating at unity power factor.

The effect of power factor upon the heat losses is more important in the converter than it is in any machine that carries alternating current alone.

Fig. 4 shows a certain amount of leading reactive current which, combined with the same energy current as before, produces the total alternating current shown. It is evident that this leading current has its highest values when the phase *a b* is in the position of zero time,

and that this current adds to the direct and alternating energy currents in that part of the phase between the tap a and the d-c. brush.

The current in any coil throughout 180 deg. of time or rotation may be determined as before.

The averaged total heating in any coil in a phase, expressed as per cent of the loss with direct current alone in the armature, is shown in Fig. 6, for power factor = 1.0, 0.95 leading, and 0.95 lagging. It will be noted that the heat losses at unity power factor are symmetrically distributed while at any power factor

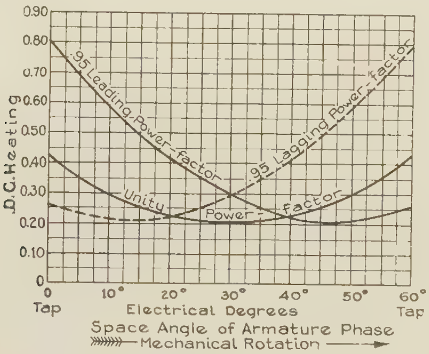

FIG. 6

other than unity the distribution is not symmetrical. Leading current causes the coils just "ahead" of the tap to overheat while lagging current reverses all these relations and overheats the coils just "behind" the tap. This fact furnishes a means of determining whether a converter armature winding has been damaged by leading or lagging power factor current.

Another important fact shown by these curves is that the heating of the coils near the tap is increased much more rapidly by low power factor than in any other type machine. In this instance of 0.95 power factor the tap heating increases from 0.43 to 0.80 or 85 per cent, whereas in any other device carrying alternating current alone, the increase is only 11 per cent. It may be stated in a general way that the tap coil heating of the converter is increased several times as fast by a change of power factor as in pure a-c. apparatus.

ARMATURE REACTION

Several of the best known textbooks treating of the armature reaction in the synchronous converter erroneously apply a "distribution factor" to the d-c. armature reaction, and neglect the factor $4/\pi$ which is the ratio of the sinusoidal component of a square wave to the amplitude of the wave itself. These errors lead to the false conclusion that the a-c. and d-c. armature reactions completely cancel each other in line with the interpoles.

As a matter of fact the armature reaction of a converter consists of a steady component and a series of even M (p) time harmonics. Their effect on commutation and flux distortion requires that they be given due consideration in design.

A conception of the physical relations and magnitude of armature reaction in the converter may be formed by referring to Fig. 7. The direct and alternating currents and their m. m. fs. are considered separately, and then superimposed to form a resultant. A six-phase converter has been chosen, with full pitch, infinitely distributed windings. Thus each phase belt covers 60 electrical degrees and differs by the same amount in time phase from the adjacent belt.

In part I the direct currents are represented as flowing into the plane of the paper under pole N and out of this plane under pole S. According to the usual convention these currents are assumed to be paired so as to constitute turns about the neutral or quadrature axis. The m. m. f. of these direct currents is thus a triangular wave.

In a similar way the m. m. f. distribution due to the alternating current can be obtained, as shown in parts II and III for two different positions of the armature.

Assuming for convenience unity power factor, and choosing c as reference phase, the currents may be represented as

$$i_a = I \sin(\omega t - 120 \text{ deg.}),\ i_c = I \sin(\omega t)$$
$$i_b = I \sin(\omega t - 60 \text{ deg.}),\ i_a = I \sin(\omega t + 60 \text{ deg.})$$

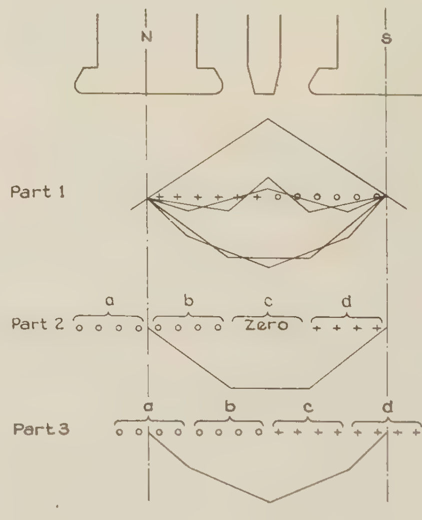

FIG. 7

where ωt is the displacement of the mid point of c from the quadrature axis. Thus for $\omega t = 0$ phase belt c is in the position of zero voltage and current, that is centered on the neutral axis. The other two currents are

$$i_b = I \sin(0 - 60 \text{ deg.}) = -0.866\, I$$
$$i_d = I \sin(0 + 60 \text{ deg.}) = +0.866\, I$$

Thus the currents i_b and i_d at this particular instant are equivalent to magnetizing turns around the neutral axis, and give rise to trapezoidal distribution of m.m.f.

When the common tap of b and c is on the neutral axis 30 deg. later ($\omega t = 30$ deg.) the currents are

$$i_a = I \sin(30 \text{ deg.} - 120 \text{ deg}) = -I,$$

$$i_b = I \sin(30 \text{ deg.} - 60 \text{ deg.}) = -I/2$$

$$i_d = I \sin(30 \text{ deg.} + 60 \text{ deg.}) = +I,$$

$$i_c = I \sin(30 \text{ deg.}) = +I/2$$

At this instant i_a pairs with i_d, and i_b pairs with i_c to form two bands of magnetizing turns about the neutral axis, and give rise to the polygon distribution of m. m. f. shown in part III.

These two m. m. fs., corresponding to different positions of the armature, may be superimposed on the d-c. diagram in part I and combined with it to produce the corded triple space harmonic of resultant reaction, which oscillates between these two extremes for every 30 deg. rotation of the armature, giving a 6th time harmonic.

These 6th harmonics of m. m. f. are responsible for the appearance of the "tap frequency pulsation" in the external circuit of the converter when the machine is loaded. They also increase the core loss and losses in the amortisseur winding.

There is a steady term of armature reaction under the interpole represented by the average of the two extremes shown in part I, Fig. 7. This must be compensated by extra turns on the interpole. Its small value compared to the d-c. reaction is the reason why interpoles were not adopted for converters until after their application to straight d-c. machines.

Note the presence of the cross magnetizing m. m. f. under the main poles. This demands an increased excitation with load, (due to saturation), which must be supplied either by increased field excitation, or by reactive alternating current and a change of power factor.

The Voltage Ratio. The ratio of the d-c. to the effective value of the fundamental of the a-c. voltage, as obtained from equations (**14**) and (**19**) is

$$\frac{E_{DC}}{E_1} = \frac{\sqrt{2}\cos(\psi + \gamma_1)}{\sin\dfrac{\pi}{p}}$$

$$+ \sqrt{2} \sum_{2}^{\infty}{}_{\kappa} \frac{B_\kappa C_{\rho\kappa} \sin\dfrac{\kappa\pi}{2} \sin\dfrac{\sigma}{2}}{B_1 C_{\rho 1} \sin\dfrac{\pi}{p} \cdot \sin\dfrac{\kappa\sigma}{2}} \cos\kappa(\psi + \gamma_\kappa)$$

$$= \sqrt{2}\,\Delta/\sin(\pi/p) \qquad (\mathbf{20})$$

An inspection of this equation shows that the voltage ratio of a synchronous converter is fixed by the following conditions:

a. The number of phases p in the ratio $\sqrt{2}/\sin(\pi/p)$, called the *normal* ratio of the synchronous converter.

b. The brush shift ψ, limited because of sparking for shifts large enough to affect the ratio more than a few per cent.

c. The flux shifts γ_1 and γ_m have the same effect, theoretically, as the brush shift ψ, but are more feasible practically since the brush may be left in the artificial neutral zone of the commutating poles, and sparking thereby avoided.

d. Superposition of those flux harmonics of odd order which are multiples of the number of phases per pair of poles. The voltages due thereto are cancelled out in the phase by the distribution of the winding, but appear in the d-c. voltage and thus change the ratio. Other harmonics in the flux may be used to change the ratio, but not so effectively, since they change both the a-c. and d-c. induced voltages, and consequently, they cause harmonic currents to flow which tend to neutralize the flux harmonics by armature reaction and reactance; and increase the transformer heating; but may or may not increase the converter heating.

Note that the even multiple of p harmonics are ineffective since they are cancelled out entirely in the d-c. voltage by the factor $\sin m\,\pi/2$. For this reason it is impossible to vary the voltage of a two-phase, four-phase, or two n-phase machine by superposition of multiple of p harmonics. However the voltage of a six-phase machine may be varied by superimposing the odd multiple of (3) harmonics, provided that the transformer connections are open circuited to the flow of the third harmonic current and its multiples.

Such connections are equivalent to the use of a six-phase converter as a duplex three-phase machine.

Items c and d constitute the regulating pole method of voltage variation.

e. The armature winding factors are the angle σ between adjacent coil sides, the per cent pitch ρ and the pitch coefficients $C_{\rho 1}$ and $C_{\rho m}$. In commercial machines σ is usually less than 12 deg., and $1.00 > \rho > 0.95$.

In addition to the above there are several other influences on the voltage ratio which do not appear in the equation. They are:

f. The brush short-circuits the voltage across its bearing arc, but this decrease of net voltage is too small to be of any practical importance.

g. The armature impedance and brush resistance drops change the voltage ratio with the load.

h. The armature reaction contains a steady term and a series of even multiple of p harmonics. The steady term is of little practical importance, but the harmonics of armature reaction in conjunction with g; cause the so-called "tap frequency pulsations" to appear in the terminal voltages.

i. The oscillation about its mean position of the belt of conductors between brushes, and the variation in reluctance of the magnetic circuit due to the passage of the slots under the poles, cause a "tooth frequency pulsation" to appear in the voltage. This tooth frequency pulsation is high enough to prove objectionable on account of telephone interference when the feeders run parallel to telephone lines. It may be eliminated by spiralling the armature slots.

In present day practise it has been found more satisfactory for operating and economic reasons to vary the terminal voltage of the converter rather than change its ratio by flux distortion. This may be accomplished by the following means:

j. Tap changing transformers or voltage regulators.

k. Booster converters, in which a small alternator is connected in series with the converter. The voltage is controlled by manipulation of the booster field excitation. In smaller machines the booster is usually a separate machine with a revolving field, but in the larger sets it is made integral with the converter proper and has a revolving armature. Direct-current boosters are not as satisfactory since they have the disadvantage of a commutator capable of carrying the full converter output.

l. Field controlled converters, in which a change in the excitation changes the power factor. The reactive component of current flowing through the external reactance of the transformers or of separate reactors, changes the voltage at the converter slip rings, and thus the d-c. voltage.

Current Ratio. The current ratio of the synchronous converter follows from the law of conservation of energy

$$\text{d-c. output} = \text{a-c. input} \times \text{efficiency} \qquad (21)$$

$$\therefore E_{DC}\, I_0 = p\, E_1\, I_1 (1 - \zeta) \cos \theta \qquad (22)$$

where

$\cos\theta$ = power factor

I_1 = eff. value of a-c. current

ζ = rotational losses as per cent of a-c. input.

$$\therefore I_1 = \frac{E_{DC}}{E_1}\,\frac{I_0}{p\,(1-\zeta)\cos\theta} = \frac{\sqrt{2}\,\Delta I_0}{p \sin \frac{\pi}{p}\,(1-\zeta)\cos\theta} \qquad (23)$$

Appendix II

Armature Heating

On the assumption of linear commutation and a brush overlap of b radians the direct current in the layer

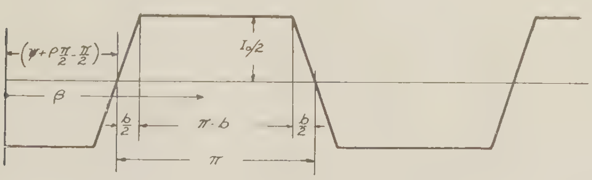

Fig. 11

of conductors between adjacent brushes is a trapezoidal wave as shown in Fig. 11. The Fourier series of this wave reckoned from the quadrature axis is

$$i_{dc} = \frac{4 I_0}{\pi b} \sum_{1}^{\infty}{}_{\kappa} \frac{\sin (2\kappa - 1)\, b/2}{(2\kappa - 1)^2} \sin (2\kappa - 1) \left(\beta - \psi + \rho\frac{\pi}{2} - \frac{\pi}{2}\right) \qquad (25)$$

The alternating current in a phase is, in general

$$i_{ac} = \sum_{1}^{\infty}{}_{m} I_m \sin m\,(\omega t + \theta_m) \qquad (26)$$

If the phase belt has c coils of pitch $\rho\,\pi$, uniformly distributed by the angle σ, then at any time t the position with respect to the quadrature axis of the $(r+1)$ *th* coil of the belt is, by Fig. 9

$$\beta = \left[\omega t + \frac{\pi}{2}(1-\rho) - (c-1)\frac{\sigma}{2} + r\,\sigma\right] \qquad (27)$$

The substitution of (27) in (25) thus specifies the direct current in the $(r+1)$ *th* coil at any instant. The resultant current in this coil is the difference of the alternating and direct current, and is

$$i_{r+1} = \sum_{1}^{\infty}{}_{m} I_m \sin m\,(\omega t + \theta_m)$$

$$- \frac{4 I_0}{\pi b} \sum_{1}^{\infty}{}_{\kappa} \frac{\sin (2\kappa - 1)\, b/2}{(2\kappa - 1)^2} \sin (2\kappa - 1)$$

$$\left[\omega t - \psi - (c-1)\frac{\sigma}{2} + r\,\sigma\right] \qquad (28)$$

The average loss per cycle for this $r + 1$th coil is

$$W_{r+1} = \frac{1}{\pi}\int_0^{\pi} R\, i_{r+1}^2\, d\,(\omega t) \qquad 29)$$

where

R = resistance of the coil.

The substitution of (28) in (29) yields integrals of the following types

$$\int_0^{\pi} \sin^2 a\,x\,.\,d\,x = \pi/2 \qquad \int_0^{\pi} \cos^2 a\,x\,.\,d\,x = \pi/2$$

$$\int_0^{\pi} \sin a\,x\,.\cos a\,x\,.\,d\,x = 0 \qquad \int_0^{\pi} \sin a\,x\,.\cos b\,x\,.\,d\,x = 0$$

$$\int_0^{\pi} \sin a\,x\,.\sin b\,x\,.\,d\,x = 0 \qquad \int_0^{\pi} \cos a\,x\,.\cos b\,x\,.\,d\,x = 0$$

$$a \neq b \qquad (30)$$

If, now, $2\,s - 1$, denote those harmonics having the same order in both the m and κ series; that is, those for which

$$m = (2\kappa - 1) = 2\,s - 1) \qquad (31)$$

then by the relations of (30) it is easy to show that (29) becomes

$$W_{r+1} = \frac{R}{2} \sum_{1}^{\infty}{}_{m} I_m^2$$

$$+ \frac{R}{2}\left(\frac{4 I_0}{\pi b}\right)^2 \sum_{1}^{\infty}{}_{\kappa} \frac{\sin^2 (2\kappa - 1)\, b/2}{(2\kappa - 1)^4}$$

$$- R\left(\frac{4 I_0}{\pi b}\right) \sum{}_{s} I_{2s-1} \frac{\sin (2\,s - 1)\, b/2}{(2\,s - 1)^2}$$

$$\cos (2s-1)(\lambda_{2s-1} + r\sigma) \tag{32}$$

where

$$\lambda_{2s-1} = \left[-(c-1)\frac{\sigma}{2} - \psi - \theta_{2s-1} \right] \tag{33}$$

The last summation of (**32**) can not, in general, be evaluated since its limits and arguments are all indefinite. But the second summation on the right of (**32**) can be evaluated by the methods of analysis shown in Appendix V. It is

$$\frac{R}{2}\left(\frac{4 I_0}{\pi b}\right)^2 \sum_1^\infty {}_\kappa \frac{\sin^2 (2\kappa - 1) b/2}{(2\kappa - 1)^4}$$

$$= \frac{R I_0^2}{4}\left(1 - \frac{2b}{3\pi}\right) \tag{34}$$

$$\text{for } \pi \geq b \geq 0$$

Since in practise b is of the order of ¼ radian it is seen that the effect of brush over lap is to reduce the losses in a conductor by the order of 3 per cent of the total armature current heating. It is therefore of no importance. Obviously, since we have shown the effect of brush over lap to be insignificant for any conductor it will also be negligible for the whole armature heating. Let us then, for simplicity, pass at once to the limit by allowing $b \to 0$ in our equations. Then (**32**) reduces to

$$W_{r+1} = \frac{R}{2} \sum_1^\infty {}_m I_m^2 + \frac{R I_0^2}{4}$$

$$- 2R\frac{I_0}{\pi} \sum {}_s I_{2s-1} \frac{\cos (2s-1)(\lambda_{2s-1} + r\sigma)}{(2s-1)} \tag{35}$$

The average heating of the whole armature is

$$W = \sum_0^{c-1} {}_r \frac{W_{r+1}}{c} = \frac{R}{2} \sum_1^\infty {}_m I_m^2 + \frac{R I_0^2}{4}$$

$$- 2\frac{R I_0}{\pi c} \sum {}_s \sum_0^{c-1} {}_r I_{(2s-1)} \frac{\cos (2s-1)(\lambda_{2s-1} + r\sigma)}{(2s-1)} \tag{36}$$

Effecting the r summation as shown in Appendix IV we obtain

$$W = \frac{R}{2} \sum_1^\infty {}_m I_m^2 + \frac{R I_0^2}{4}$$

$$- \frac{2}{\pi} R I_0 \sum {}_s I_{(2s-1)} \frac{C_{d\,(2s-1)}}{(2s-1)} \cos(2s-1)[\psi + \theta_{2s-1}] \tag{37}$$

The usual text book expressions are obtained herefrom by introducing the following simplifying assumptions.

1. Normal voltage ratio, $\Delta = 1$
2. 100 per cent pitch, $\rho = 1$
3. Infinite distribution, $\sigma = 0$, $c = \infty$
4. Fundamental a-c. current only.
5. $\tau = r\sigma - (c-1)\frac{\sigma}{2}$ = position of a coil from middle of the phase belt

$$W_{r+1} = \frac{R I_0^2}{4}\left\{1 + \frac{8}{p^2 \sin^2 \frac{\pi}{p} (1-\zeta)^2 \cos^2 \theta} - \frac{16 \cos (\tau - \theta)}{\pi p \sin \frac{\pi}{p} (1-\zeta) \cos \theta}\right\} \tag{47}$$

$$W = \frac{R I_0^2}{4}\left\{1 + \frac{8}{p^2 \sin^2 \frac{\pi}{p} (1-\zeta)^2 \cos^2 \theta} - \frac{16}{\pi^2 (1-\zeta)}\right\} \tag{48}$$

The sensitivity of the heating to the power factor ($\cos \theta$) requires that the converter be run at or near unity power factor.

It is obvious from equation (**47**) that the heating is a maximum at one or the other of the outside conductors of the phase belt; that is, at the "tap" coils. At unity power factor it is the same for both tap coils, but at any other power factor it is increased at one tap and decreased at the other.

The Resultant Armature Reaction. The resultant armature reaction is the sum of the a-c. and d-c. reactions as given by equations (**62**) and (**71**).

It is

$$F_R = \frac{Z}{\pi} \sum_1^\infty {}_\kappa \sum_1^\infty {}_m \frac{\sin \kappa\pi/2}{\kappa} C_{\rho\kappa} C_{d\kappa} I_m$$

$$\{\cos [(\kappa' - m)\omega t + \kappa'\beta - m\theta_m]$$

$$- \cos [(\kappa'' + m)\omega t + \kappa''\beta + m\theta_m]\}$$

$$+ \frac{Z}{\pi} \sum_1^\infty {}_\kappa \frac{\sin^2 \kappa\pi/2}{\kappa} C_{\rho\kappa} C_{d\kappa}' I_0 \cos \kappa (\beta - \psi + \rho\pi) \tag{76}$$

Or for 100 per cent pitch, infinite distribution and the fundamental current only

$$F_R = \frac{Z}{\pi^2} \sum_1^\infty {}_\kappa \frac{\sin^2 \kappa\pi/2}{\kappa^2} \left\{ I_1 p \sin \frac{\kappa\pi}{p} \right.$$

$$(\cos [(\kappa' - 1)\omega t + \kappa'\beta - \theta_1]$$

$$\left. - \cos [(\kappa'' + 1)\omega t + \kappa''\beta + \theta_1]) - 2 I_0 \cos \kappa (\beta - \psi) \right\} \tag{77}$$

The quadrature and direct components are given by substituting $\beta = 0$ and $\beta = \pi/2$ respectively; or can be obtained by adding the corresponding components

of the a-c. and d-c. reactions from equations (**65**), (**66**), (**74**), and (**75**). Thus, using (**23**)

$$F_{RQ} = \frac{Z\,I_0}{(1-\zeta)}\left\{\frac{2\cos\theta_1}{\pi^2\cos\theta}\,\Delta - \left(\frac{\pi - 2\,\psi}{4\,\pi}\right)(1-\zeta)\right.$$

$$+\frac{2}{\pi^2}\,\frac{\Delta}{\cos\theta}\sum_{2}^{\infty}{}_{\kappa}\,\frac{\sin\kappa\,\pi/p\,.\,\sin^2\kappa\,\pi/2}{\kappa^2\sin\pi/p}$$

$$\left.(\cos[(\kappa'-1)\,\omega\,t-\theta_1] - \cos[(\kappa''+1)\,\omega\,t+\theta_1])\right\} \quad (\mathbf{78})$$

$$F_{RD} = \frac{Z\,I_0}{(1-\zeta)}\left\{\frac{2\sin\theta_1}{\pi^2\cos\theta}\,\Delta + \frac{\psi}{2\,\pi}(1-\zeta)\right.$$

$$+\frac{2}{\pi^2}\,\frac{\Delta}{\cos\theta}\sum_{2}^{\infty}{}_{\kappa}\,\frac{\sin\kappa\,\pi/p\,.\,\sin\kappa\,\pi/2}{\kappa^2\sin\pi/p}$$

$$\left.(\sin[(\kappa'-1)\,\omega\,t-\theta_1] - \sin[(\kappa''+1)\,\omega\,t+\theta_1])\right\} \quad (\mathbf{79})$$

Since k is always odd, and since $\kappa \pm 1 = M\,(p)$ by the definitions of k' and k'', it follows that

$$\frac{\sin\kappa\,\pi/p}{\sin\pi/p} = \frac{\sin[M\,(p)\pm 1]\,\pi/p}{\sin\pi/p} = \pm 1 \quad (\mathbf{80})$$

where the $-$ sign is to be associated with k'' and the $+$ sign with k'.

Except in the case of the booster and regulating pole types of converters the distortion of the field flux is negligible, so that the voltage is practically zero at the instant that the phase is central with the pole. It is evident, therefore, that the angle θ_1 is nearly the same as the power factor angle θ. Then for the simple converter (**78**) and (**79**) simplify to

$$F_{RQ} = \frac{Z\,I_0}{(1-\zeta)}\left\{\frac{2}{\pi^2}\,\Delta - \left(\frac{\pi-2\,\psi}{4\,\pi}\right)(1-\zeta)\right.$$

$$+\frac{2\,\Delta}{\pi^2\cos\theta}\sum_{2}^{\infty}{}_{\kappa}\,\frac{\sin^2\kappa\,\pi/2}{\kappa^2}$$

$$\left.\times(\cos[(\kappa'-1)\,\omega\,t-\theta] + \cos[(\kappa''+1)\,\omega\,t+\theta])\right\} \quad (\mathbf{81})$$

$$F_{RD} = \frac{Z\,I_0}{(1-\zeta)}\left\{\frac{2}{\pi^2}\,\Delta\tan\theta + \frac{\psi}{2\,\pi}(1-\zeta)\right.$$

$$+\frac{2\,\Delta}{\pi^2\cos\theta}\sum_{2}^{\infty}{}_{\kappa}\,\frac{\sin\kappa\,\pi/2}{\kappa^2}$$

$$\left.\times(\sin[(\kappa'-1)\,\omega\,t-\theta] + \sin[(\kappa''+1)\,\omega\,t+\theta])\right\} \quad (\mathbf{82})$$

Now $k \pm 1$ is always even, and since k' and k'' are only particular values of k it follows that the harmonics of armature reaction are always even and $M\,(p)$. Also, for every $k'-1$ term there is a $k''+1$ term of the same order, because for every value of $M\,(p)$ values of k can be chosen such that $k'-1 = M\,(p) = k''+1$.

Thus the armature reaction of a converter consists of a steady term and a series of even $M\,(p)$ harmonics. The pulsations in the m. m. f. due to these harmonics show up in the oscillograms as the so-called "tap ripple." This ripple is not present at zero load because the armature reaction is then zero. In the case of the quadrature reaction these pulsations occur under the interpole and seem to have some influence on commutation.

For unity power factor and zero brush shift the steady term of the direct component of armature reaction disappears; but contrary to general opinion the quadrature component does not vanish under these conditions.

Chief interest lies in the quadrature component since it acts on the neutral zone and must be compensated by extra turns on the interpoles. As an instance, take a six-phase converter for which $\zeta = 0$, $\theta = 0$, $\psi = 0$, and $\Delta = 1$. Then its quadrature component of armature reaction is

$$F_{6\phi} = Z\,I_0\,\{\,.037 + 0.013\cos 6\,\omega\,t + 0.003\cos 12\,\omega\,t + 0.001\cos 18\,\omega\,t + \ldots\} \quad (\mathbf{83})$$

Thus a 6th harmonic pulsation exists of about ⅓ the magnitude of the steady term. Due to this pulsation the armature reaction varies from about 10 per cent to 20 per cent of the d-c. armature reaction. Of course the ordinary series winding of the interpole does not neutralize these pulsations of m. m. f.

List of Symbols

- b = Brush width expressed in electrical radians
- B_κ = Amplitude of flux density for the κth harmonic
- c = Coils per phase belt
- $C_{p\kappa}$ = Pitch factor of the κth harmonic
- $C_{d\kappa}$ = Distribution factor of the κth harmonic
- e = Instantaneous voltage induced in a coil
- e_p = Instantaneous voltage induced in a phase
- E_{dc} = D-c. induced voltage
- E_1 = Effective value of the fundamental of a-c. induced voltage
- F = Polyphase armature reaction
- F' = D-c. armature reaction
- F_R = Resultant armature reaction

  (for F, F', F_R:) Subscript D for direct component. Subscript Q for quadrature component.
- i_{ac} = Instantaneous a-c. phase current
- I_1 = Fundamental of a-c. current (eff. value)
- I_m = Amplitude of the mth harmonic of a-c. current
- I_0 = D-c. brush current
- m = Time harmonic of the a-c. current
- $M(\;)$ = Multiple of ( )
- n = Number of turns per coil

p = Number of phases per pair of poles
r = Index for the $(r + 1)$th conductor in a phase belt
R = Resistance of an armature coil
t = Time counted from instant when the phase is centrally located with respect to the poles
Z = Total number of conductors per pair of poles
α = Space angle measured on the armature
β = Space angle measured on the field
γ_κ = Flux shift of the κth harmonic of flux distribution
Δ = Distortion factor of the converter
ζ = Rotational losses as fraction of the a-c. input
θ_m = Phase angle of the mth time harmonic of a-c. current
θ = Power factor angle
κ = Space harmonic
κ' = Any value of κ for which $\pm\ (m - \kappa) = M\ (p)$ or 0
κ'' = Any value of κ for which $(m + \kappa) = M\ (p)$
ρ = Pitch expressed as a fraction
τ = Position of a coil from the middle of the phase belt
σ = Distribution angle of the coils
ψ = Brush shift from neutral position
ω = $2\,\pi f = 2\,\pi$ (frequency).

Symposium on High-Frequency Measurements

By Committee on Instruments and Measurements

A. E. KNOWLTON, Chairman

THE following article consists of a resume of a series of fifteen papers dealing with measurements at high frequencies. The study of this subject, the preparation of these papers and their presentation will constitute the major activity of the Committee on Instruments and Measurements during the year 1926-27. The papers are to be presented at the Regional Meeting in Pittsfield, Mass., May 25, 1927. Complete copies may be obtained from Institute headquarters. The papers are as follows:

1. *Notes on the Use of a Radio-Frequency Voltmeter,* by W. N. Goodwin, Jr.
2. *Substitution Method for the Determination of Resistance of Inductors and Capacitors at Radio Frequencies,* by C. T. Burke.
3. *Condenser Shunt for Measurement of High-Frequency Currents of Large Magnitude,* by Alexander Nyman.
4. *Radio-Frequency Current Transformers,* by Paul MacGahan.
5. *Methods for the Measurement of Radio Field Strengths,* by C. R. Englund and H. T. Friis.
6. *The Quantitative Determination of Radio Receiver Performance,* by H. D. Oakley.
7. *High-Frequency Measurements of Communication Lines,* by H. A. Affel and J. T. O'Leary.
8. *Methods of Measuring the Insulation of Telephone Lines at High Frequencies,* by E. I. Green.
9. *High-Frequency Measurement of Communication Apparatus,* by W. J. Shackleton and J. G. Ferguson.
10. *Impedance of a Non-Linear Circuit Element,* by E. Petersen.
11. *Empirical Analysis of Complex Electric Waves,* by J. W. Horton.
12. *A New Thermionic Voltmeter,* by S. C. Hoare.
13. *The Oscilloscope: A Stabilized Cathode-Ray Oscillograph with Linear Tome Axis,* by Frederick Bedell and H. J. Reich.
14. *Sensitivity Characteristics of a Low-Frequency Bridge Network,* by P. G. Edwards and H. W. Herrington.
15. *Microammeter Indication of High-Frequency Bridge Balance,* by H. M. Turner.

The committee feels that these papers reflect the latest development in the methods of measurement of quantities associated with frequencies ranging from those just above power and ordinary telephone frequencies through those used in radio communication.

The instruments commonly employed in measurements at ordinary power frequency have very definite limitations when used at the higher frequencies. Also it is a matter of common knowledge that measurements of circuit properties under the higher frequencies cannot in general, be made satisfactorily by direct determination of current and voltage drop in a series arrangement. Much of the progress in the field of high-frequency measurements has been in the direction of bridge modifications, adaptation of the electron tube to measurement circuits, and also the improvement of thermocouple type instruments.

Instruments for Radio Frequencies

A shielded thermocouple type voltmeter for radio frequencies was described by L. T. Wilson in the 1924 TRANSACTIONS. The current consumption varies from 2 to 8 milliamperes for the conductive circuit of the instrument and a quadrature component for shield-charging of the same order of magnitude. Subsequent investigation during the development of the instrument have shown that in order that the inherent precision of the instrument shall be realized, the effect of inductance and capacitance in the connections must be avoided by observance of careful technique. Thus

in measuring the effective resistance of a reactor, the low-potential section of the measuring circuit should be carefully grounded and the high potential section kept short and clear of solid dielectrics and consequent stray loss.

In measuring the R and L of a broadcast tuning coil, for example: It is connected in series with a 500-m. m. f. condenser, a 100-milliampere ammeter and a 1.2-ohm resistor (say 2 in. of 0.0065-in. manganin) the latter serving as conductive coupler with an oscillator 10-watt or larger. The drop across the resistor as indicated by the voltmeter will be of the order of three volts when the measuring circuit is tuned to sharp resonance. The effective resistance of the coil is less than E/I by the amount of milliammeter and condenser resistances. The inductance of the coil is computed from the resonance formula and the capacity setting of the condenser. The frequency error of this device is about 1 per cent for frequencies of the order of 1500 kilocycles. (See paper No. 1).

Circuit constants of capacitors and inductors are, in one method, of a substitution type; found by resonating them in a series circuit and using as an indicator a crystal in series with a d-c. microammeter, the combination shunted across a small inductance in the series circuit.

The resistance of an inductor is found in the value of a non-reactive resistor substituted for the inductor in a circuit tuned in both cases to resonance by adjustment of a capacitor having negligible equivalent series resistance. The inductance is found in terms of the quotient of difference and product of the capacities required for resonance. Similarly, the capacitance and resistance of a capacitor are found in terms of the change in resistance and capacitance between resonance, with and resonance without the capacitor in question. (See paper No. 2).

In the measurement of high-frequency current of more than 10 amperes the hot wire instrument is not feasible because the size and resistance tend to become prohibitive. The thermocouple ammeters for larger ranges than 100 amperes become very expensive on account of considerations of skin effect and size of heating element. Iron-cored current transformers are satisfactory up to 500 kilocycles but for much higher frequencies the difficulties in design increase.

A method has been developed which employs a hot-wire or thermocouple ammeter in series with a relatively small condenser and the combination in parallel with a large condenser shunt. The error due to the thermocouple resistance need not exceed 0.5 per cent with frequencies up to 6000 kilocycles and satisfactory commercial measurements are feasible up to 60,000 kilocycles. Unit assembly of the shunt condenser readily permits the provision of several current ranges, —say 50, 100, 200 amperes, the thermocouple instrument in each case having a 0.25-ampere rating. Care must be taken to avoid losses from resonance of the closed circuit at some harmonic of the fundamental. The absolute calibration of the arrangement presents difficulty even by means of a calorimeter ammeter because of the uncertainty about high-frequency resistance and effect of distributed capacity. The condenser shunt is apparently entitled to greater confidence than a direct thermal determination. (See paper No. 3).

For the measurement of large currents at high frequency, there are also available current transformers of the through-type with secondary rated at one ampere; the indicator is usually a thermocouple type ammeter. (See paper No. 4).

Radio Field-Strength and Receiving Sets

The vacuum tube used as detector, amplifier and voltmeter is the basis of sensitive comparator methods for determining radio field strengths at frequencies below 1000 kc. in the customary unit of micro volts per meter. The loop-antenna is employed in preference to the open-antenna and no indirect evidence has appeared which places in doubt the value of equivalent effective height computed for the loops used. Both the $I\,R$ drop and mutual-inductance voltage methods are employed for introducing into the antenna the sinusoidal comparison voltage; the resistance method is preferred because its reactance is of less concern than the resistance of a mutual inductance and also it serves admirably as a terminal impedance for a constant impedance attenuation network. Shielding is easier with resistance coupling.

For frequencies higher than 1000 kc. the above method becomes unworkable and a double-detection type of receiver is used after calibration as a vacuum tube voltmeter. The received field strength is evaluated in terms of three measured attenuation factors, the received signal voltage and the loop effective height. Static energy and static "noise value" are of interest; continuous static is readily measurable in terms of the telegraph signal strength masked by it. The enormous variability of usual static has prompted measuring it by noting the gain of the receiving set necessary to maintain constant static output. A nonrestoring type of deflection instrument comparable to a fluxmeter has merit in summing the received energy over a definite interval. (See paper No. 5).

The problems of measurement of the common electrical properties of the individual elements and of circuit units of radio receiving sets having been dealt with, there are remaining those factors of set performance which differentiate sets with respect to their selectivity, sensitivity, fidelity of reproduction and reradiation. Each of these attributes of a completed set have been reduced to a quantitative definition and measuring method which evaluates them in terms of output voltage obtained on response to the input from a controlled signal generator. Thus sensitivity is determined as the ratio of output voltage to input field strength at various output voltages and input frequencies. Dimensional analysis of the expressed ratio

results in reduction to length units; therefore, sensitivities are expressed in meters. Selectivity is determined in terms of the input field strength required to maintain a constant minimum value of output voltage for the requisite range of frequencies. Quality performance is expressed as the ratio of output voltage at the various modulation frequencies, the antenna voltage and degree of modulation being maintained constant. Radiation is expressed in meter-amperes, the meters being the antenna height and the amperes that value of current required to establish various output voltages in a detector of known sensitivity when the latter is supplied with the radiation output of the receiving set. (See paper No. 6).

Telephone Carrier-Frequency Measurements

In the field of telephone carrier frequencies, the line characteristics of chief interest are attenuation, impedance and cross-talk for frequencies up to about 50,000 cycles. Apparatus for field and laboratory measurement of these quantities has been developed and standardized on a unit basis. The units consist of oscillator, detector-amplifier, impedance-bridge, thermomilliammeter, variable attenuator, cross-talk set and frequency meter. The oscillator is a vacuum-tube and tuning circuit giving 0.4 to 0.7 watts maximum at frequencies from 100 to 50,000 cycles and above 3000 cycles has no harmonics of more than 10 per cent of the fundamental amplitude. The detector-amplifier is adapted to both aural and visual balancing or indication. The impedance bridge is of the balancing or differential coil type. The thermomilliameter carries its own d-c. calibrating circuit and provides for the use of three thermocouples of a range of characteristics to cover a current range from 0.2 to 50 milliamperes. The attenuator is a network of known loss and terminal impedance and the cross-talk-set is a similar attenuator adapted to cross-talk measurements of the order of 10^{-6} times the transmitted currents. The frequency meter is a resonance bridge. Attenuation measurements made on the current-transmitted versus current-received method are possible for energy ratios up to 30×10^6 to an accuracy of about 3 per cent. Impedance measurements are of importance in connection with non-homogeneous lines and these are generally made on the line after terminating it in its characteristic impedance, usually a resistance of about 600 ohms; the results indicate the efficacy of loading to meet carrier-current operation. Avoidance of cross-talk with carrier-frequency operation presents many difficulties and necessitates a highly refined system of transpositions; the cross-talk measurements made to determine the effectiveness of the transpositions are a specialized form of attenuation measurements, *i. e.*, attenuation to cross-talk must be high and to line transmission low.

It is by such a system of measurement that a telephone circuit is tested for its quality after the necessary modifications have been made in preparation for carrier-current operation. (See paper No. 7).

A substantial part of the increased attenuation at carrier frequencies is due to skin effect of the conductors, and the leakage conductance of the insulators is found to increase rapidly with the frequency; radiation is a negligible factor. It is permissible to attribute to leakage conductance all losses except those of an $I^2 R$ nature in the metallic conductors; the leakage conductance, G, may of course, be derived from measurements of the attenuation but the line would have to be at least 100 mi. in length. A direct measurement of G on a line short enough (250 ft.) to avoid propagation effects and a phase shift of more than five degrees has been made on an experimental line with sufficient comparability to represent the shunt losses in long lines; the line contained 25 poles spaced 7 ft. apart and with 6-in. spacing of the insulators on the crossarms. A certain amount of transposition was resorted to, but the important precautions pertained to the manner of leading the conductors into the test station.

Each circuit is in effect a conductance shunted by a capacitance and thus the equivalent of the leaky condenser; the bridge for the conductance measurements is similar to those employed for the determination of the loss angle or power factor of dielectrics and condensers. The high resistance of a few insulators in parallel would appear to require a correspondingly high value of resistance in the standard side of the bridge but this is avoided by placing a condenser in series with a lesser value of resistance. A method of obtaining continuous record of d-c. leakage has been developed; a similar continuous record of the high-frequency leakage is greatly to be desired but as yet awaits solution. (See paper No. 8).

The performance of communication apparatus depends principally upon its impedance and in the precision and routine measurement of resistance, inductance and capacitance, standards of primary and secondary nature are necessary. The prime standards may well be resistance and frequency and the derived standards those of inductance and capacitance. Self-driven forks (calibrated by phonic wheel for 24-hr. period against Arlington time) can be maintained within 0.001 per cent of 100 cycles. Other frequencies can be compared with the standard by means of the cathode-ray oscillograph. Resistance standards must have minimum and constant phase angle; 1000-ohm standards have been constructed with effective inductance not exceeding five microhenrys up to 100 kc.

Secondary standards of capacitance are made with mica dielectric impregnated with paraffin; such condensers can be obtained with temperature coefficient below 0.005 per cent per deg. cent. and with less than 0.1 per cent capacitance variation from 500 cycles to 100 kc. and phase angles less than one minute. Air condensers are feasible for the smaller capacitances. Secondary standards of inductance must be constant

and preferably with small external field. Air-cored standards of large inductance involve considerable distributed capacitance; on this account cores of permalloy have been used with considerable success. Secondary standards of resistance in dial form inevitably involve more distributed capacitance than single primary standard resistances.

In the comparison of secondary standards against primary standards, methods which determinate the unknown in terms of circuit constants are preferable to those requiring the measurement of current and voltage. The bridges used must be carefully shielded and the equal ratio arm bridge is to be preferred wherever possible. The bridge circuits in use provide for impedance determinations when direct current is superposed on the high-frequency alternating current; these bridge methods also provide means of measuring flutter (telegraph impulse affecting the telephone frequency inductance of apparatus in the common circuit), transformer ratios, capacitance unbalance, attenuation and gain, and cross-talk. (See paper No. 9.)

The harmonic components of non-sinusoidal quantities create difficulties in the measurement of impedance of circuit-elements of a non-linear nature, where the ratio of instantaneous currents and potentials is not constant throughout the cycle. Vacuum tubes are non-linear as to resistance and iron-cored coils at high flux densities are non-linear as to reactance. In a-c. bridge measurements of such quantities it is found that the measured impedance depends on harmonic factors introduced from the source of supply, the magnitude of the resistance in the bridge ratio-arms, the impedances of the detector and of the source of supply to the fundamental frequency and to the possible harmonic frequencies, and also upon the method used in attaining bridge balance. As for the last item, the measured non-linear impedance may well be different if balanced, in one case, against standards of resistance and inductance and, in the other case, balanced against a non-inductive resistance after establishing resonance with a standard capacity.

It is thus often essential to arrange the measuring circuit so that the impedance or other quantity measured shall be characteristic of the non-linear device and not of the bridge and supply network. The complicating effect introduced by a non-sinsuoidal impressed potential wave is readily removed by the use of a frequency-selective circuit between the source and the measuring network. The complicating effect of harmonics arising out of the non-linear reaction of the element under measurement may be suppressed in two ways,—one, a modification of the usual bridge method and the other, an a-c. potentiometer method.

In the modified bridge method, two balanced high-inductance coils with high-coupling are inserted in the 1:1 ratio bridge arms. The fundamental fluxes neutralize but the harmonic components of current encounter the series-aiding impedance and are effectually suppressed. In the a-c. potentiometer method the harmonics are suppressed by a filter of low impedance to the fundamental and high impedance to the harmonics developed in the non-linear element. Further modifications make possible the determination of the non-linear characteristics of the element without suppressing the harmonic current flow. (See paper No. 10).

In the transmission of speech it is not only essential that the circuit possess prescribed reactions to steady state conditions but also that it fulfill certain other limitations upon transient conditions. The oscillograph is inadequate to the analysis of the couples waves encountered in, for example, the multi-channel repeater employed in carrier telephone systems and other means of analysis had to be devised. Any distortion by amplifiers or circuit elements results in the development of new frequencies that are multiples of the components of the impressed wave or are algebraic combinations of those components; these extraneous components may call for detection and measurement when their amplitude is even as low as 0.1 per cent or less of the true signal components. The heterodyne beat method is found useful in such detection and measurement; by a d-c. indicator in the plate circuit of a biased grid tube the amplitude of the d-c. component is directly determined. The same indicator will by relatively slow periodic change in deflection show by a beat method the presence of a minute component of a particular difference-frequency when the oscillator frequency is brought close to the frequency of the component. The method does not lend itself readily to a quantitative determination however.

Practically all analyzers for waves of small amplitude are modifications of the elementary form in which a selective circuit couples a vacuum tube amplifier to the circuit under investigation. Whether the voltage drop across L or C be chosen for application to the grid of the detector depends upon the frequency of the components sought; L for low, and C for high frequencies. The procedure is tedious and long if a wide range of frequencies are sought and there has been developed a device for automatically tuning over the desired range and automatically recording the amplitudes of discovered components. Means are also available for examining the variation of a single component of a complex wave as conditions affecting it are varied; the required selectivity is attained by employing several analyzers in tandem.

For more exacting requirements even the above method is inadequate and for such cases a heterodyne analyzer has been developed; thereby the frequency range to be examined is translated to a lower position of the frequency scale with the advantage of greater fractional separation between components. (See paper No. 11).

Instruments for Moderately High Frequencies

A vacuum tube voltmeter has been developed in which the plate impedance forms one arm of a Wheatstone bridge. With zero voltage impressed upon the grid-filament circuit of the tube the bridge is initially balanced by means of an adjustable resistance, the bridge indicator then reading zero. When an unknown voltage either alternating or direct is then impressed upon the grid-filament the plate-impedance changes, and the bridge balance is disturbed; the resulting deflection of the bridge indicator is a direct indication, after appropriate calibration, of the voltage impressed on the grid filament. (See paper No. 12).

Professor Bedell describes a method for producing stationary curves on the screen of a cathode-ray oscillograph and establishing a linear time axis which involves the use of an auxiliary circuit consisting of a source of constant voltage, a neon gas-filled lamp and an electron-tube arranged in the general form of a bridge. The voltage across a portion of this circuit, which varies directly with time, is connected across one pair of deflecting plates of the oscillograph tube and in this way establishes a linear time axis. By means of a motor-driven distributor, the other pair of deflecting plates is connected first to one part of a circuit and then to another, thus making it possible to study several phenomena simultaneously. (See paper No. 13).

The employment of very low frequencies (say three or four cycles per second) involves in some respects as much difficulty as the higher frequencies. The problem of locating opens in telephone cable conductors involves the determination of impedances; a study has been made of the degree of accuracy and sensitivity obtainable in impedance measurement with different frequencies of supply voltage. For long cables the input impedance is a hyperbolic rather than linear function of the characteristic impedance; the error in impedance measurement arising from this functional departure proves to be least for the lower frequencies. On the other hand, the bridge sensitivity is improved by somewhat higher frequencies. A thorough mathematical and experimental analysis of the sensitivity of impedance measurement of cable fault locations up to 70 mi., by means of a de Sauty bridge, indicates the desirability of using frequencies of the order of four cycles. The sensitivity is further increased by controlling the phase of the field excitation of the bridge galvanometer. Use of such low frequencies as four cycles per second is not common and the generating apparatus, bridge, detector, and graphical treatment of errors and sensitivity of measurement of impedances at this frequency are of interest in a report on measurements under other than power frequencies. (See paper No. 14).

The telephone receiver, due to its simplicity, sensitivity and convenience, has been widely used for determining a-c. bridge balance and under favorable conditions is quite satisfactory. The aural method, however, involving as it does the receiver associated with the ear, has two serious limitations; first, it can be used only where there is very little extraneous noise and second, the frequency range for best operation is restricted to a band of, say, from 200 to 2000 cycles unless a heterodyne scheme is adopted.

A visual method has been devised using a d-c. microammeter in the plate circuit of an electron tube rectifier, associated with one or more stages of amplification, which gives maximum reading for a state of balance, thereby permitting the use of a sensitive meter and at the same time making it fool proof. A large bridge unbalance reduces the deflection to nearly zero and as balance is approached it increases. No change in reading on short-circuiting the indicator terminals of the bridge, which would correspond to zero voltage, shows definitely a perfect balance. This method not only completely overcomes the limitations of the aural method, but also renders a quantitative determination of the degree of unbalance. (See paper No. 15).

TOOLS OF DESTINY

Scientists, inventors and engineers are working in an age when practical development follows rapidly the discovery of a new truth in science. In the eyes of electrical explorers, the electron is the energy mite which enfolds an ever-enlarging vista, and radio and television are merely indicative of what will soon come. In a recent address, Dr. E. F. Alexanderson expressed his conviction that the power industry cannot long remain untouched by the new discoveries in electricity. It is waiting until the new knowledge has been widened and matured so that it can be put to use on a larger scale, and this is the real significance of the excursion of so many electrical men into radio and television. Electric power as it is known so far is only an introduction, and the finished chapters are still to be written as the evolution in the art progresses.

Recent developments afford material for widly speculative predictions which far surpass the imaginative pictures of certain romantic writers. For example, we can visualize a very short wave used as a power conveyor. Through reflection from a so-called parabolic mirror, a broad beam of radiation can be focused along which energy in quantity can be conveyed. At the receiving end, the turning of a switch sets an oscillator into operation and light and heat are made available. If such a radiated beam renders the air conductive, then low-frequency energy could be transmitted without wires and no tuning receivers would be needed. This idea is not new, for Tesla started to build such a power house many years ago. The thing that is new is more complete knowledge whereby such ideas become practical. Even the use of short-wave, high-frequency energy to heat people in homes and offices is an experimental fact which may have a commercial application in the distant future.—*Electrical World.*

Discussion at Winter Convention

THE SYNCHRONOUS CONVERTER THEORY AND CALCULATIONS[1]

(Hambleton and Bewley)

New York, N. Y., February 8, 1927

E. B. Shand: From the standpoint of practical design calculations, I believe that the formulas in the complex forms given are not generally applicable, due to the fact that the accuracy of design calculations is limited by a number of factors not considered in the paper. An instance of this may be found in equation (**20**) for voltage ratio. This expression may be simplified very greatly by introducing coefficients obtained directly from the converter field form without going through the process of actual harmonic analysis, which have a greater degree of accuracy than those of the calculated field form.

The expressions for the armature-loss constants vary from those ordinarily employed in that the effect of non-sinusoidal alternating currents is included. In working with converters the difficulty in determining actual armature losses is due to the fact that the phase relations between the alternating and direct currents within the armature are not expressed completely by the phase angle of the currents at the collector rings, due to the internal phase displacement within the converter itself. This difference in loss may be greater than 50 per cent in certain cases. Certain data and the manner of estimating the armature losses under these conditions have already been published.[2] I believe that equations (**45**) and (**46**) should be modified to allow for these conditions.

In the discussion of armature reaction, it is stated that "the 6th harmonics of m. m. f. are responsible for the 'tap-frequency pulsation' in the external circuit of the converter when it is loaded." In my own experience with converters I have often found this pulsation to be just as great with no load on the converter when the reaction should be negligible, as with full load. This would preclude the generality of the above statement. In cases given some investigation, it has been found that the pulsation was due mainly to the fact that the converter with its 3rd and 5th, (etc.) harmonics in the generated voltage wave had been connected to a power system of low impedance and with a voltage closely approximating a sine wave. The harmonics had therefore to be absorbed to a large extent within the converter itself by pulsating fluxes produced by harmonic currents. These pulsating fluxes generated the voltage variations found in the d-c. voltage and which naturally must repeat themselves with every tap. These harmonic currents are particularly apparent when the converter is operating at very light loads.

One more comment might be applied to the paper in a general way. Its usefulness would probably be increased if the symbols used in the appendices were more completely defined.

Quentin Graham: I note that the authors have not discussed the average heating, or total loss, of all coils in the converter. They have shown very clearly how the heating of individual coils varies with coil position and power factor and might easily have gone a step further and included the average heating or loss. The latter is important if the efficiency is to be calculated under various conditions. I am submitting herewith a curve, Fig. 1, which shows the average heating constant for six-phase converters with the assumption of no rotationa losses, and another set of curves, Fig. 2, shows the variation of the heating constant for six-phase converters under conditions of varying power factor and varying ratio of d-c. to a-c. power. The authors' equations contain a factor which depends upon this ratio although it is defined in terms of efficiency or rotational losses. If the ratio of d-c. to a-c. power is allowed to vary through a wide range as in Fig. 2 the results are applicable to cases in which mechanical power is either put into or taken out of the shaft. Such curves are useful in connection with booster converters, for example, in which the booster machine is coupled to the converter shaft.

It is interesting to note that the minimum heating or loss does not occur when the input and output are equal, but that a small amount of power put in through the shaft is necessary to reach the minimum point on the curve. As the power factor becomes lower the minimum point recedes farther from the point of pure converter operations.

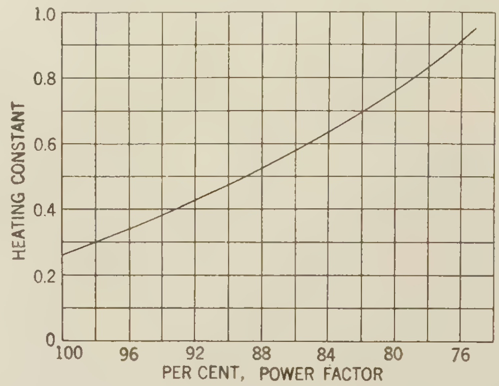

Fig. 1—Curve Showing Average Heating or Loss Constant for 6-Phase Synchronous Converters With Equal Input and Output

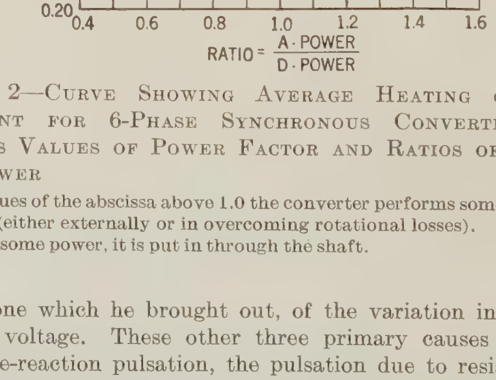

Fig. 2—Curve Showing Average Heating or Loss Constant for 6-Phase Synchronous Converters for Various Values of Power Factor and Ratios of A-c. to D-c. Power

For values of the abscissa above 1.0 the converter performs some mechanical work (either externally or in overcoming rotational losses). For values below 1.0 some power, it is put in through the shaft.

L. V. Bewley: In regard to Mr. Shand's remarks, the tap-frequency pulsation is due to three primary causes, in addition to the one which he brought out, of the variation in the a-c. applied voltage. These other three primary causes are; the armature-reaction pulsation, the pulsation due to resistance of the windings, and the pulsation due to the variation in reactance of the windings as the windings take up successive positions. We did not attempt to take up the effects of other than sinusoidal voltage, but we did take up armature reactions, and the impedance variation has been very fully covered by Mr. Lyndville

1. A. I. E. E. Journal, May, 1927, p. 479.

2. Operation of Synchronous Converters at Reduced Voltages, *Electrical Journal*, Dec. 1924.

in England in the *Electrical Review* of 1917, the November issue.

In regard to Mr. Graham's remarks, equation (23) which gives the current ratio, gives also the factor η. If the machine has a mechanical load that is represented by a booster converter, then there is mechanical friction and that factor η can take care of the torque on the shaft. In the case of the equation, it is general as far as the mechanical loads are concerned, although we explicitly stated that we do not consider any machine in general except the simple converter. I merely bring this up to show that the equations are extensible to other converters.

Also in addition to what Mr. Graham says, if you want to carry things farther and take up considerations of the variable-ratio converter, split-pole converter, then the distortion of the flux causes motor reaction. If you take the armature reactions and average it from the middle of an adjacent pole to the main pole, you will find from the fundamental alone the armature reaction depends upon $(s - 1) - (\eta - 1)$. Therefore, the average armature reaction averaged over the pole pitch depends upon not only the distortion but also upon the field form.

T. T. Hambleton: I agree entirely with Mr. Shand that the complication involved in the formula which we have developed would render it unsuitable for ordinary everyday use. The formula we already have in use is good enough.

There is another point of interest in addition to those mentioned by Mr. Graham relative to armature heating. This is a comparison of the increase in armature copper loss of the converter and other machines carrying only alternating current as the power factor is lowered.

A curve may be drawn using power factor as ordinates and per cent increase in copper loss as abscissas. A few points on these curves are as follows:

Power factor	Converter heating (tap coil), per cent	A-c. machine heating (all coils), per cent
1.00	100	100
0.97	165	106
0.95	190	111
0.90	248	123
0.80	375	156

This shows why the converter is essentially a unity-power-factor machine and illustrates the danger of departing from specified power factors.

REDUCTION OF ARMATURE COPPER LOSSES

(SUMMERS)

NEW YORK, N. Y., FEBRUARY 8, 1927

G. H. Rockwood, Jr.: In order to compute the losses in these transpositions which Mr. Summers has described, it is necessary to determine the percentage of slots in the winding having a given value of the angle θ between current in the top and bottom coil sides. Necessity for visualizing the winding may be done away with and the computation simplified by the following procedure:

In a three-phase winding of full pitch, the angle between the currents in the top and bottom coil sides of all slots is zero; for a two-thirds pitch winding, it is 60 deg.; for a one-third pitch winding, 120 deg., and for a zero pitch winding, 180 deg. Between these limiting values, the percentage of coils having a given value of the angle θ will vary linearly with pitch. We may, therefore, plot the data of Table II of the paper, as is done in the accompanying Fig. 1, and obtain a family of curves for each transposition. Such a plot will enable us to omit the rather laborious computation in the paper, and to read the reduction factor for circulating current directly as a function of the coil pitch.

P. L. Alger: Mr. Summers' idea of making an inversion in one or more turns at the ends of an armature winding seems to me to be a very simple and satisfactory method of avoiding eddy currents. In Schenectady, in building a considerable number of large machines, we have used it with very good success. The advantage of the method is that it enables a standard machine-wound coil to be made without the extra expense of special insulated clips, the connecting of adjacent coils, or any other complications. All other schemes that have been proposed before have involved some inconvenient departure from the simple standard manufacturing processes, and so their use has not seemed to be warranted unless the circulating-current loss without transposition was more than about 25 per cent. With the new method, we have found it desirable to transpose the winding whenever the circulating-current loss should exceed approximately 10 per cent without it.

It is true that the inverted-turn idea is very similar indeed to those which have been suggested by H. W. Taylor in England, and by others; but so far as I know, no one has proposed exactly the same scheme, nor has anyone worked out, completely, the eddy-current loss formulas for this case. I feel, therefore, that Mr. Summers has made a very distinct contribution to the art of electrical machine design.

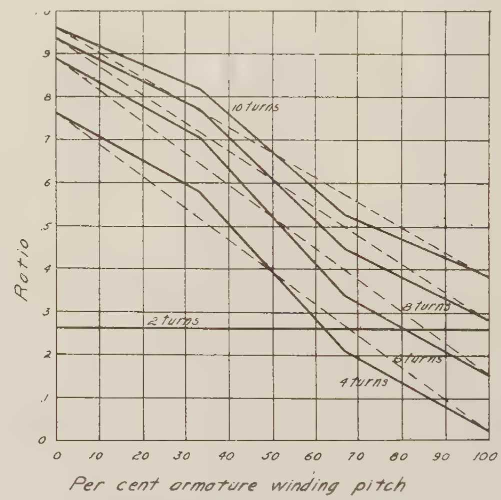

FIG. 1—RATIO OF EXTRA LOSS IN TYPE IV WINDING TO THAT IN TYPE I.

Full line—3 phase.
Dash line—2 phase.

J. R. Dunbar: I desire to point out that the method of transposition advocated by Mr. Summers was used by H. B. Dwight on experimental coils for machines that were being manufactured by the Canadian Westinghouse Company. At that time, it was decided that the reduction in eddy-current losses was insufficient to justify the added complication in the winding of the coils for the machines then being considered. I should like to ask Mr. Summers if it is proposed to use in machines now under construction any of the transpositions he describes?

F. D. Newbury: It may be of interest to point out a few of the more general considerations affecting transposition. There have been three methods advocated: First, there is transposition secured by means of certain connections between coils. That method has been applied for 10 or 12 years in large machines and is effective and economical in such cases. The second method is to transpose the conductors within the armature slot. That is a method which has been used in Europe very considerably but not in this country until recently. In Europe, designers have used partially closed slots; we have used open slots. They have used straight bar conductors joined by separate end connectors in these partially closed slots. This construction with transposition within the slot, is fairly simple. Designers in this country

have taken up this construction in recent years in large machines because coils became so long that it was desirable to deal with half coils instead of complete coils, and it is only possible to deal successfully with half coils when it is possible to connect both ends of the conductor solidly in forming the complete winding. So in American practise, in our largest machines the transposition within the slot is coming into use.

It seems to me that this third method advocated and described by Mr. Summers is a very desirable construction for the moderate-sized machine where it is still desirable to use complete coils, machine-wound, and to secure transposition economically.

In looking over the bibliography at the end of this paper[2] there is another thought that occurs to me. It illustrates the greatly accelerated progress in the mathematical and theoretical bases of our design work. From this bibliography you will note that the earliest American paper was one by A. B. Field, presented in 1905. There was no other important contribution, at least, not in America, until Gilman's paper in 1920,—a period of fifteen years. In the six or seven years since that, we have had the important papers by Prof. Lyon, and now another one by Mr. Summers, which indicates the very healthy condition of progress in this branch of design.

C. M. Laffoon: I wholly subscribe to the views given in the paper; in fact, I used the method a few years ago.

W. V. Lyon: I agree with Mr. Summers that in the computation of the extra-loss factor for any winding that is properly designed, it is sufficiently accurate to use the first terms in the expansion of the hyperbolic functions. This is also the expressed opinion of H. W. Taylor. For anyone who might wish to compare the approximate with the exact values of these hyperbolic functions, I am appending a table of such values.

I should like to call attention to one minor correction. It is in regard to the use of the ratio r when calculating the strand loss. This ratio takes into account the effect of the insulation between the strands. The magnetic field that exists in the space between adjacent strands plays its part in affecting the distribution of current among the strands and thus is a factor in determining the circulating-current loss. On the other hand, this magnetic field does not influence the strand loss. The expression for the strand loss can be corrected by using either a different value for the ratio b or the ratio r. The effect of this correction will be to multiply the strand loss by the ratio of (the net depth of strand)^2 to (the gross depth of strand).^{2} Making this correction in Mr. Summers' numerical example reduces the strand loss factor from 0.094 to 0.082.

I believe that there are still one or two points in the theory of these extra losses that are not fully appreciated. The extra circulating-current loss is zero when the current is equally divided among the strands. The extra strand loss is not a minimum for this condition, however, but for the condition when the current is more concentrated toward the top of the slot. As a simple illustration of this, consider two equal strands placed one above the other. The total loss in these strands is a minimum when the current in the lower strand is one-half of the total multiplied by the fraction $\left(1 - \frac{N}{M}\right)$ and the current in the upper strand is one-half of the total current multiplied by $\left(1 + \frac{N}{M}\right)$. As further evidence of this fact, consider the expressions for strand loss that were derived in my 1922 paper.[1] In case 5 of that paper, the circulating-current loss is much smaller than in case 6, but the strand loss is smaller in case 6 in about the ratio of 13 to 16 for full-pitch slots and in about the ratio of 10 to 13 for three-phase fractional-pitch slots. It is readily shown that in the windings which have a small circulating-loss factor, it is very nearly correct to compute the strand loss on the assumption that the current is equally divided among the strands, as Mr. Summers has done. The exact expression for the strand loss is readily deduced by following the method outlined in my 1922 paper. It is:

$$\left\{ \frac{1}{2\,n} \left(\sum_{D} \left| I_b \right|^2 + \sum_{R} \left| I + I_b \right|^2 \right) - \left| I_o \right|^2 \right\} T_r'$$

The notation is the same as in my paper. The value of n is the number of turns in the coil. The first term is the sum of the squares of the currents in the slot *below* the successive half turns of the coil in which the strands are numbered in the direct order. The second term is the sum of the squares of the conductor current plus the current in the slot below the successive half turns of the coil in which the strands are numbered in the reverse order. The last term is the square of the current I_o. Mr. Summers describes the method of computing I_o.

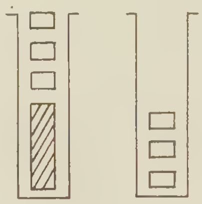

FIG. 2

For a given depth of copper in the slot, the strand loss can be reduced to a reasonable value by increasing the number of strands. For a given number of strands it is nearly independent of the strand arrangement. The circulating-current loss, on the other hand, depends in a marked degree upon the strand arrangement. The problem then seems to be to reduce this latter loss to its smallest possible value.

With full-pitch slots, Mr. Summers' quantity, L, has its smallest value when $\frac{I_o}{I} = -\frac{1}{2}$, for which condition $L = -\frac{1}{4}$. This then gives the condition for minimum circulating loss. This value of $\frac{I_o}{I}$ can always be obtained, if the coil has an even number of turns, by inverting the end connections as shown in his Fig. 3. It can also be obtained if the coil has an odd number of turns provided the current in the lower coil side is in phase with that in the upper coil side. Figs. 2 and 3 herewith show how it may be accomplished when the coil has three turns and when it has five turns. Mr. Summers does not show this type of inversion. It will be found, however, in H. W. Taylor's paper. With these same inversions, the losses will be somewhat greater for fractional-pitch slots. There is another type of inversion, however, that will give more nearly the theoretical

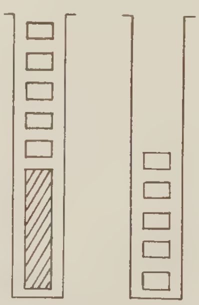

FIG. 3

1. *Heat Loss in Stranded Armature Conductors*, W. V. Lyon, TRANS. A. I. E. E., 1922, p. 199.

minimum loss for the case of an odd number of turns and fractional-pitch slots. In the case of three-phase, fractional-pitch slots, the minimum value of L is $-\frac{1}{18}$ if the coil has three turns. The arrangement is the same as shown in my Fig. 2, except that the lower conductor of the lower coil side is inverted. For three-phase, fractional pitch slots, arranged as shown in Fig. 2, L is zero. If the conductors have a value of $q\,h$ equal to 2.0, which is not excessive, the inversion of this bottom conductor reduces the circulating-current extra-loss factor from 0.309 to 0.245 for these fractional-pitch slots. Although fractional pitch has certain distinct advantages from the standpoint of flux distribution and wave form of generated e. m. f., it prevents the attainment of the minimum copper-loss factor except in the single case of a winding having an even number of turns arranged as in Mr. Summers' Fig. 3.

There is one more case that is perhaps worth while mentioning. A certain large 25-cycle generator has a calculated extra-loss factor of 9.9 per cent. If it had been mechanically possible to invert the end connections, as in Mr. Summers' Fig. 3, the extra-loss factor would have been 0.6 per cent, a reduction of 8.5 per cent in the armature copper loss. For the same armature heating loss the rating of this generator might have been increased nearly 2000 kv-a. There might possibly have to be a slight modification of the field winding to compensate for the increased armature reaction.

TABLE OF APPROXIMATE AND EXACT HYPERBOLIC FUNCTIONS

$q\,h$	M Exact	$1 - \frac{(q\,h)}{45}$ Approximate	N Exact	$-\frac{(q\,h)^4}{12}$ Approximate
0.4	1.001	1.00058	0.002	0.00213
0.8	1.008	1.0091	0.034	0.0342
1.2	1.044	1.0461	0.169	0.173
1.6	1.137	1.146	0.512	0.546
2.0	1.309	1.356	1.147	1.333
2.4	1.566	1.738	2.074	2.766
2.8	1.874	2.368	3.17	5.12

H. W. Taylor (communicated after adjournment): When a coil consists of two or more turns, methods of reversing the order of laminations of the conductor in different parts of the coil have been previously known whereby the circulating-current loss may be reduced to a minimum, which minimum loss corresponds to that of a conductor at the bottom of the slot, consisting of half the laminations of the conductor actually used in the coil.

Sometimes it is found inconvenient, however, to arrange all the coil ends so as to change the order of the lamination in the top and bottom conductors as frequently as is required to provide a minimum loss. The author of this paper is to be congratulated upon having disclosed in Fig. 6 a method of winding multi-turn coils which provides a compromise between facility in winding the coil on the one hand and reduction of the circulating eddy-current losses on the other.

In order to consider the merits of the various forms of coil windings with laminated conductors, the writer has found it convenient to consider the circulating loss only and as if the conductor were infinitely limited. The term in the formula for extra loss in an infinitely laminated conductor which involves the position of the conductor in the slot is

$$\frac{4}{45} - \frac{(p^2 - p)}{3}$$

where p is the position of the conductor counting from the bottom of the slot.

In the following table, particulars have been tabulated for two- up to six-turn coils for the ordinary method of winding, for the most perfect method, and for Summers' method as described in the paper. In the table, parallel columns give equivalent values of p, the value of $(p^2 - p)$ and the value of the above expression (leaving out the denominator of 180 in all cases), as a figure of merit.

No. of turns in coil	Ordinary Method p	(p^2-p)	Fig. of merit	Most Perfect Method p	(p^2-p)	Fig. of merit	Compromise Method p	(p^2-p)	Fig. of merit
2	1½	¾	61				0	0	4
3	2	2	136				1/3 or 2/3	−2/9	3
4	2½	15/4	241	½	−¼	1	¼ or ¾	−3/16	5
5	3	6	376				1 1/5	6/25	59
6	3½	35/4	691				1 1/3	10/9	83

It will be seen that the author's method is particularly applicable to two-, three-, and four-turn coils. It provides considerable improvement in five- and six-turn coils, but owing to the fact that in coils with this larger number of turns, the total depth of conductor would be relatively shallow, the loss in such coils would in practise, be small in any case.

I. H. Summers: Mr. Rockwood has presented a very interesting and valuable discussion. His curves should materially simplify the computation of extra-loss factors. They will be especially valuable in design work where it is highly desirable to have a quick and convenient method for checking the efficacy of proposed windings.

Mr. Dunbar has stated that H. B. Dwight experimented with transpositions similar to those I have described but gave up the idea because of the belief that the reduction in loss was insufficient to justify their use. Mr. Alger has answered this statement by pointing out that a considerable number of large machines have already been built using these transpositions with good success and that it is found economical in Schenectady to use the transposition whenever the extra circulating eddy-current loss would exceed about 10 per cent without it. It will be noted that some of the types of transpositions described are more effective than others. Naturally, in any given winding, that method will be selected which combines a sufficient reduction of eddy-current loss with economy in making the winding.

With regard to Mr. Newbury's points about the applicability of various types of transpositions to particular classes of windings, I may say that there is no gain to be expected from the inverted-turn transposition when it is applied to a one-turn coil. For machines using a one-turn coil, an effective form of transposition is already in extensive use, which completely eliminates the circulating eddy-current loss. The transposition in this case is accomplished within the slot, and a bar winding, consisting of half coils, is used.

H. W. Taylor's discussion is very interesting. His tabulation shows that type IV Fig. 6, is particularly applicable for two-, three-, and four-turn coils, when the winding is full-pitch. I wish to remark that type V, Fig. 7, is quite applicable also for two- and three-turn coils; in fact it gives a lower loss than type IV if the coils are wound with fractional pitch. For coils of four or more turns, type IV is preferable in any case.

I am very much indebted to Prof. Lyon for calling attention to an error in the use of the ratio r. The correction for the strand insulation was not a part of the original manuscript but was sent in as an after thought. Obviously, it should have been applied to the circulating-current loss but not to the strand loss. Perhaps the best way to take care of this is to define r simply as the ratio between the total width of copper in the slot and the slot width. Then, a new factor c should be introduced into the formula for circulating-current loss wherever it occurs, where c is the square of the ratio between (strand height including strand insulation) to (net strand height).

Prof. Lyon's remarks concerning the problem of strand loss are pertinent and it is interesting to note that his exact results lead him to the conclusion that my formulas are sufficiently accurate for practical windings. Perhaps it is in place to point out that the first duty of the engineer who sets out to provide a solution to a problem is to solve it in the most general and exact manner that he can devise. Prof. Lyon has done this in a neat and logical way. In so doing, he has provided a firm foundation for anyone who later wishes to apply his results. It is often possible in such cases to reduce the general solution to a more practical form which will be the simplest possible, consistent with the accuracy required. Thus, it may be simplified so that practical men will find great use for it. This is what I have attempted to show in my paper.

DESIGN OF REACTANCES AND TRANSFORMERS WHICH CARRY DIRECT CURRENT[1]

(HANNA)

NEW YORK, N. Y., FEBRUARY 8, 1927

D. C. Prince: The first question that came into my mind was, what is the real measure of these reactances? The reasoning that I went through is something like this: if we have a certain small variable current that is produced by a ripple voltage in the case of a rectifier or by whatever the alternating impulse is, and then we have a steady direct current that must be carried, the function of the reactor is to keep the ratio of the incremental current, the variable current to the direct current, as small as possible.

Or, looking at it the other way, we want to make the ratio of the direct current carried to the incremental current as large as possible. The incremental current will be inversely proportional to the reactance. So if we simply put a constant representing $2 \pi F L$, we find that we can consider that the measure of the performance of our piece of apparatus is proportional to the product of current and inductance.

Mr. Hanna has considered that the current should be squared, and I will be interested in hearing why he squared it, but while I am about it, I might as well carry the story on, upon the basis that we used, which was taking the first power of current instead of the square as our measure.

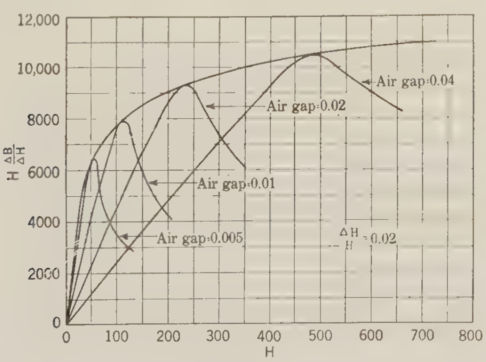

FIG. 1

Referring to the accompanying Fig. 1, the product of inductance and current is taken vertically; the current is horizontal. Then for any particular air-gap we will get a curve of the sort, shown rising to a peak and then falling again. For the larger air-gap, the curve rises to a higher value at a higher current, and if we secure a number of such curves and then proceed to draw a curve that includes them, you will find that as the air-gap increases, the effectiveness of our inductance also increases, and it appears to approach a constant value somewhere in the neighborhood of corresponding to an air-gap of approximately 4 per cent of the total mean magnetic path.

1. A. I. E. E. JOURNAL, February, 1927, p. 128.

That leads then to the question, "Why don't we always make the air-gap at least 4 per cent or more as long as the curve seems to be steadily climbing upward?" The answer to that is more or less suggested in Mr. Hanna's paper, although no direct attention was drawn to it. This small air-gap reactor giving its maximum inductance at a low value of current, when you design it is made almost wholly of iron, has hardly any copper in it. As you go in the direction of greater and greater air-gaps, you get larger and larger ratios of copper to iron, and if you are making a large piece of apparatus such as the reactor to smooth out the current from the rectifier, it becomes very important to strike a balance between the copper and iron. For very small pieces of apparatus

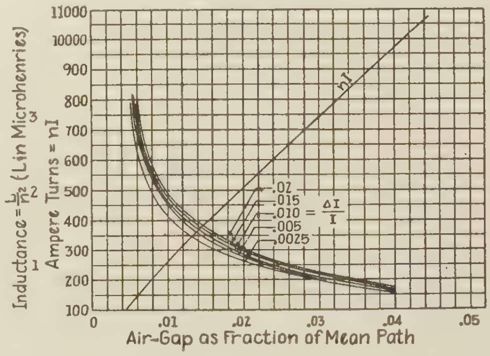

FIG. 2—CURVE SHOWING EFFECT OF AIR-GAP ON INDUCTANCE OF UNIT REACTOR, (1-IN. CUBE) WITH n TURNS PER INCH AND EFFECT ON AMPERE-TURNS FOR LEAST PULSATION FACTOR

of course that is less important, but for the larger things such as the chokes for radio transmitters and the filter reactor for rectifiers, the dominant thing is to strike a balance between copper and iron so as to get the most economical structure.

To that end we arrived at a plot slightly different from the one which Mr. Hanna has used. We plot inductance for the unit volume and air-gap, and then we have another plot giving the relation between the air gap and the ampere-turns as shown in Fig. 2 herewith. Taking such a plot as that, you simply assume a series of air-gaps for each one of which you can design a reactor immediately, and then having such a series the most economical one may be chosen, and the actual reactor built from it.

There is just one other point about the paper. Mr. Hanna has been dealing with very small increment of current, and as the alternating components increase, the effective reactance also increases, and we have thought it necessary, therefore, to have not one curve for the minimum variation in current but a group of curves so that we can design for what the demanded current pulsations are.

C. R. Hanna: I have converted one of the curves given in Mr. Prince's Fig. 2 to which he has called attention. The best air-gap is along the abscissas, one curve representing ampere-turns and the other $\frac{L}{N^2}$. These two curves could be properly converted into one if the scale of ampere-turns were plotted along the $\frac{L}{N^2}$ - curve.

I took the lowest curve, interchanged air-gap with ampere-turns and multiplied ordinates by the square of the abscissas, converting his curves into the same form that I have given in my paper.

As has been brought out, he considered much greater values of steady magnetization or steady ampere-turns per centimeter than I did.

The lowest of the several curves was chosen because it repre-

sents the smallest percentage variation in current. That corresponds more closely to mine than any other because I considered very small minor hysteresis loops.

The derived curve when extrapolated came slightly lower than mine all the way. Of course, the difference in material might account for this, but I was wondering if it might not be in the way his maxima were arrived at.

D. C. Prince: As I understand it, Mr. Hanna has struck the one real difference in the fundamentals. The question is whether the curve in Fig. 1 goes through a series of peaks or is a curve that is tangent. Mr. Hanna has made his curve tangent to the family and not through the peaks, and his method is undoubtedly correct. That is, the two give slightly different values and in his terms you get slightly higher values if you take your curve tangent to the family than you do if you go through the peaks. However, he is dealing with small values of air gap and the reactors that we actually build usually run more than 1 per cent air gap, and when you get more than 1 per cent air gap, the tangent and the peak come so close together that the choice is immaterial.

C. R. Hanna: As Mr. Prince has pointed out, the envelope curve rather than the curve through the maxima should be used. Mr. Prince raises the question as to why $L\,I^2$ was used instead of $L\,I$ as in his work. I had no particular preference in the matter, but when the results are obtained by employing values of μ_Δ corresponding to very small changes in magneto-motive-force instead of those which correspond to a constant $\frac{\Delta I}{I}$, the results will inevitably be in terms of I^2 instead of I.

J. F. H. Douglas: My interest in this topic is chiefly from the standpoint of Heising modulation choke coils. I wish to state that I think this paper is an important theoretical advance in the design of transformers and chokes carrying direct current. It gives a better gap for maximum inductance. However, I must point out that it is still a trial-and-error method for evaluating the necessary volume in the iron core.

The values of $L\,I^2/V$, which are roughly proportional to the energy storage per unit volume, indicate flux densities in the gap by rough calculations that I have made of only 24,000 lines per sq. in., or roughly 4000 gausses and represent an inefficient use of the iron material.

It is true in radio receiving apparatus that material cost is not such an important item, and the problem is economically handled in this particular case since the size of wire which is used though not stated here can hardly be much larger than No. 30 B & S gage, and the use of any smaller iron core would result in an impossible winding problem and an unworkable air-gap.

One of my senior students, Herbert Wareing, has designed and built and installed a Heising radio choke rated for an ultimate of 10,000 volts, 2 amperes and 60 henrys. The method that he used was one which, with slight modifications, I have taught for five years for low-frequency chokes and one which was derived from Professor Karapetoff.

I wish to say that I am opposed to empirical methods of design whenever rational foundation can be found. The rational foundation in Professor Karapetoff's method in the design of transformers and, I believe, chokes, is that of economical, specific, magnetic, and electric loadings and it should be gratifying to note its wide range of application.

There are other very important factors in the design of a Heising choke besides that of securing maximum inductance for a given core. Mr. Wareing reported to me that one important factor was leakage flux from the poles of the iron parts. Another was the distributed capacity between windings, and a third was the saturation which occurred when modulating low-pitched sounds of perhaps 20 or 30 cycles frequency.

The choke coil which he replaced resembled one of the old Edison bipolar dynamos, and it showed more inductance when the Keeper was entirely removed than when it was in place. The leakage flux alone saturated the legs at the corner point where they joined the yoke.

The choke that Mr. Wareing designed had a core weighing 220 lb. and copper coils of about 200 lb. The value of $L\,I^2/V$ was 74×10^{-4}, some six times greater than the maximum value recorded by Mr. Hanna's graph. The direct-current density was in the neighborhood of 60,000 lines per sq. in., roughly 10,000 gausses, the double air-gap 1¼ in., roughly 3 cm. the core 6 in. square, the length of the magnetic circuit, exclusive of air 46 in., and the ratio of air-gap to the mean magnetic path 2.7 per cent.

Obviously in Heising chokes of this rating we must use material efficiently, and a cut-and-try method for securing the iron core would not be entirely satisfactory. Since the installation of the choke coil, the music, by station W K A F where it is in use is reported to have much better quality of modulation than previously.

I would be interested to know whether the ratio of air gap to mean magnetic path for these higher magnetic densities checked the values that Mr. Hanna advocates, or whether it more closely checks those that Mr. Prince advocates.

Mr. Wareing intends to publish his results in one of the radio publications.

C. R. Hanna: In regard to Professor Douglas's discussion, I want to say first that the value of $L\,I^2/V$ does not represent the energy storage per unit volume because L is the incremental inductance of the winding while I is the steady magnetizing current. So his calculation of the flux density from that figure is not correct. He mentioned about 4000 gausses as the density he determined in this way. The actual densities for the range of ampere-turns per centimeter given in the paper are about 6000 or 7000 gausses. Of course the density is greater for larger values of $N\,I/l$. The scope of the paper was limited, however, to reactors and transformers having small steady m. m. fs.

A NEW 132,000-VOLT CABLE JOINT[1]

(Simons)

New York, N. Y., February 9, 1927

D. W. Roper: Mr. Simons has introduced several new points in cable-joint design for which he should receive due credit.

We have used a few of these joints in Chicago. In making up the joints, the cable splicers and the engineers who were supervising the construction, had occasion to suggest one comparatively minor change which they thought would improve the joint. The change was not acted upon or received with any great degree of enthusiasm and we did not urge it. However, in giving some further thought to the subject and in looking over some of the patents that have been issued on joints to others, we discovered that the suggestion which we had made for a change in this particular joint was covered by a patent issued to another individual, and controlled by another manufacturer.

This situation appears to be getting somewhat worse and apparently it is going to become more complicated within the next few years. During the past year the industry has, for a consideration, acquired a fundamental patent covering one feature of central-station design which threatened to hamper the development of the industry, and after its acquisition threw the patent open to everybody without further charge.

If the cable joint patent situation develops into a somewhat similar state, it may be expedient for the industry to consider, in the same way, the taking over of the patents for a consideration, so that by a combination of the features, covered by the patents of various individuals, a much better joint can be made, than from the patents of any one individual or corporation.

T. F. Peterson: One point which the author emphasizes seems to me to be questionable. Failure of the composite struc-

1. A. I. E. E. Journal, March, 1927, p. 252.

ture consisting of oil, paper, etc., along the dotted line of Fig. 2 is attributed to the decreased strength of the so-called long oil path. This should be more fully demonstrated, or substantiated by proof before being adopted as to the true reason for the occurrence.

Consider the elementary case of two insulating materials in series,

lengths l_1, l_2 permittivities. K_1, K_2
gradients g_1, g_2 and applied voltage E

$E = g_1 l_1 + g_2 l_2$, and since D, density of electric displacement $= g K$ (1)

$$E = \frac{D\, l_1}{K_1} + \frac{D}{K_2}\, l_2 \tag{2}$$

$$D = \frac{E}{\dfrac{l_1}{K_1} + \dfrac{l_2}{K_2}} \tag{3}$$

$$\frac{D}{K_1} = g_1 = \frac{E}{l_1 + l_2 \dfrac{K_1}{K_2}} \tag{4}$$

When l_1, the thickness of oil path is small

$g_1 = \dfrac{E}{l_2} \dfrac{K_2}{K_1}$ = Average Gradient $\times \dfrac{K_2}{K_1}$ which is maximum value possible.

From equation (4) it is evident that as l_1 increases g_1 decreases. It seems quite improbable that, even though oil with maximum stress is not broken down, a path can be found where a lower stress is actually in excess of breakdown value. Such a condition could exist only when rate of change of strength with increase in l_1 is greater than $\dfrac{d\, g_1}{d\, l_1}$. I doubt very much whether this is the case for series oil paths less than 1 in. (Breakdown gradient of oil remains fairly constant within this range.)

I should much prefer to consider failure as being due to overstressing a comparatively short path of oil ($k_1 = 2.5$) in series with a long path of paper (k_2 = approx. 3.5). This is in accord with my experience with testing crotches, composite insulation, etc. The latter has lead to our avoiding short paths of oil in series with high-dielectric-constant materials rather than long ones.

Turning now to the joint proper, it is indeed surprising to note that the author considers the use of hard compound permissible. In Brooklyn we have a great mass of data on the migration of petrolatum compound from joints. This has seriously weakened penciled paths and necessitated refilling at 6-month intervals or continually by means of reservoirs. If this has been found necessary at 33 kv. how much more so, is it necessary to insure keeping even a "sticky" oil in paper of a 132-kv. joint.

Mr. Simons complains of difficulties experienced in wrapping metal foil on conical surfaces. We have been doing this in the field for about 1½ years, without any apparent trouble.

I am somewhat skeptical concerning the use of the machine or single paper application to three-conductor joints in metal-sheathed cable. First, the general method does not lend itself very well to jointing sector cable. Then too, its use makes it impossible to maintain a lay or twist of conductors through joints. This is of considerable advantage in "phasing out" cable. It would seem that hand wrapping must needs continue in such cases.

In concluding I might say that I consider none of the fundamental principles used in the design of the joint as being new. We have used built-up conical structures of solid insulation wrapped with metal foil—thus getting a flared zero-potential surface—for several years; stepped insulation, is standard in many joints; one-piece paper wrapping is an important feature of the Pirrelli joint.

However, the method of construction which results in the practical introduction and use of all these principles, in one operation, is decidedly unique.

S. I. Oesterreicher: Aside from the new and comparatively simple method of making an almost factory-taped insulation in the field—it seems to me—that this joint is no radical departure from other shielded cable joints.

The method of paper application may eliminate the much feared voids, however, the fact that the joint is also shielded, would indicate that there are other weak places besides voids in cable joints.

Naturally, one may ask, where?

Mr. Simons partly answers this by describing the breakdown of some extra high-voltage cable terminals which failed at a certain point on the flare of the end bell, where there was by far more insulation than in the cable proper. I have had similar

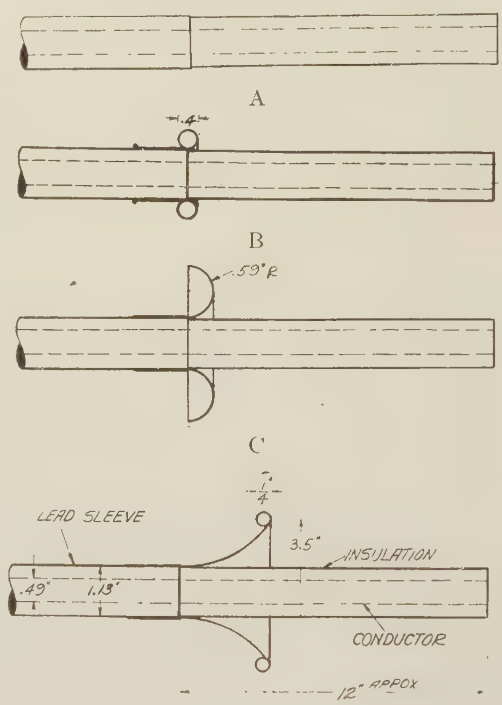

Fig. 1—Streamer Discharge Starts at A—30 Kv., B—40 Kv., C—60 Kv. and D—80 Kv. Plus or Minus 2.5 Kv.

disappointing experiences about the behavior of certain dielectrics. However, I do not believe that the insulation failed because I lowered the dielectric strength per unit thickness, but it failed because it had a greater stress along the line of breakdown than anywhere else.

In my opinion, the shape of the end bell, or that of a cable sleeve, or in more general terms the size and shape of two electrodes separated by a dielectric may considerably increase the dielectric layer stress at certain critical points.

In his classical work, Maxwell shows the field layer displacement upon unsymmetrical electrodes by his model condenser consisting of two electrodes, one a half plane, the other a full plane. While this model condenser might not be the exact duplicate of the conditions existing in a cable joint, the similarity is apparent.

Disregarding the ends and joints of a single-conductor cable, it may be represented by a concentric coaxial condenser of infinite length, or in a diagrammatic way by two symmetrical electrodes separated by a uniform dielectric. At the ends or at the joints

the symmetry of electrode arrangement is disturbed, and the internal layer stress becomes distorted. With certain assumptions, Loebner, a research worker of the Duisburg Cable Works obtained for cable ends identical curves to the ones of Maxwell's model condenser.

From this data a nomogram was constructed by which—if the normal internal cable field intensity is known, the horizontal critical stresses may be readily found.

The practical importance of this investigation is readily understood by the following diagram from Loebner's work in which four sections of the same cable are shown. The outer sleeve of each section is formed to a different shape. While the straight sleeve shows streamer discharge at 30 kv., already, the funnel-shaped sleeve may be stressed to 80 kv. before streamer discharges appear.

Thus, I believe that a cable joint insulated in the most careful manner, may be unsatisfactory if the sleeve design is not fitted to the other characteristics of the joint.

While an electrostatic shield, if properly applied does distribute the unequal strains, it will not protect without reservations.

In view of this, it seems to me that the claim in the paper, that any diameter of a sleeve may be put over the insulated joint, providing it clears the paper insulation, should not be accepted in its strict sense.

R. J. Wiseman: For testing the joints, in Table I, Mr. Simons used 200 kv. In Table II, he started with 200 kv. and then raised the voltage in steps. Now we cannot evaluate just by looking at the tables, the relative advantages of this type of joint for the two different operating voltages. If we can only decide upon some single method of testing cable joints, and then evaluate to a specified voltage stress at the conductor rather than the average stress, I think we shall all get a better idea of how good joints can be. Today we do not do it, one company uses one method and another company a different method.

W. A. Del Mar: Dr. Wiseman has made a very good point, in my opinion, in making a plea for standardization of such tests.

One of the features that should be standardized is the internal pressure of the joint when it is being tested. Ordinarily, tests on joints have been made with the joint closed in the ordinary way. When voltage is applied, there is dielectric loss, which causes a temperature rise with consequent expansion, and internal pressure in the joint. The result is that the breakdown voltage in the joint is materially increased over what it would be with atmospheric pressure.

Under the term "dielectric loss" I include and refer particularly to the energy liberated just prior to failure by destructive ionization.

This situation can be averted either by attaching a bellows device to the joint, or by leaving an opening in the sleeve, either of which will introduce atmospheric pressure. If we do not do this, a high breakdown voltage may mean nothing more or less than a high dielectric loss or ionization in the joint, and this defect would be accounted a virtue on the basis of a high breakdown voltage.

C. N. Rakestraw: I want to discuss the fact that Mr. Simons apparently takes for granted that the type of joint should be a stepped or penciled joint, as far as the insulation is concerned.

As a good many of you probably know, in connection with our development work in Cleveland about four years ago we did a siderable amount of experimenting with just this type of joint, and in fact eventually did develop a joint of wrapped or taped insulation which apparently would stand up. Our experiments showed very conclusively that one certain number of steps was preferable to anything else, and a considerably less number than Mr. Simons has shown in his diagram. As a matter of fact, of course we later found a combination still better than that, and abandoned the idea of a stepped insulation entirely. We went to a conical connector obtained by undercutting the insulation, and the use of this conical connector increased the voltage of any joint on which it was used about 50,000 volts. So it seems to me that it is a step backward to use the insulation wrapped joint.

With a joint made by cutting the original cable insulation in steps, and then wrapping these with tape, I think it is universally found that a breakdown, when a breakdown can be accomplished, starts somewhere in the center of the joint, very often under the first step or the second step, and passes almost entirely within the original insulation, and then to whatever sleeve encloses the joint.

In Mr. Simon's joint, the end is protected at an angle of about 15 deg. Now, it doesn't seem to me that the difference made by wrapping the center of the joint with one single sheet of paper as compared with tape makes a great deal of difference; but it does make a great deal of difference if the insulation is carried unbroken to the center and the central connector is protected at an angle of about 15 deg. This, as I say, has shown an increase in breakdown voltage of about 50,000 volts on this type of cable.

E. D. Eby: This paper conveys the impression that there are insurmountable difficulties in the way of making a successful joint with tape, which is economically competitive with the joint insulated with a single sheet of paper. It would seem proper to correct this impression by referring to the fact, that practically all the joints which have been made on these high-voltage cables during the past year, have been made either with paper tape or specially processed varnished cambric tape. The 75-kv. joints made in Chicago were produced complete in about 4 hr. The 132-kv. joints now being made in Chicago, I am told, are being completed in about 6 hr. In our experience, both in factory tests and customer's tests, this type of joint has proved stronger than the cable in every case. From these facts, I think it is evident that the taped joint is entirely practical.

With reference to the practise of removing the cable insulation in steps, the merit of this is well illustrated in its application to some of the Cleveland-type joints in Philadelphia, which were made with the enlarged connector having the same diameter as the conductor insulation. Some of these joints failed when the cable line was tested, apparently because of incomplete filling of the under-cut in the insulation with the solder. These joints were successfully repaired by stepping the insulation and applying varnished-cambric tape, without having to renew the cable section.

I want to add a word to the subject of testing. It is highly desirable that our tests should be comparative and I would recommend, as a basis of tests for joints and terminals, the program of testing set forth in the A. E. I. C. rules for cables. We have been following these rules in our development work on joints so that our own tests could be compared. If this program were generally used, the different designs of joints could be readily compared.

Let me emphasize also that any high-voltage joint, as well as the adjoining cable, is greatly benefited if a thin mineral oil is used as a filler. The migration of the oil into the cable, if it is not already a so-called oil-filled cable, improves the cable by preventing the formation of voids in the insulation. By placing an oil reservoir in the form of an oil-filled joint in each end of the cable section, each length of cable is fed from two directions. Some operating companies have already found that the filling of joints with oil has sufficiently improved the strength of old cable so that the operating voltage could be materially raised and successful operation secured.

D. M. Simons: Mr. Peterson apparently does not agree with me in my explanation of the failure shown in Fig. 2. There are of course two effects, namely the decreased strength of oil in thicker layers, and also the difference in specific inductive capacity between the oil and the impregnated fibrous insulation. Mr. Peterson emphasizes the latter, while I emphasize the former. The actual truth is probably a combination of the two effects, but I cannot agree with Mr. Peterson that the breakdown

gradient of oil remains constant up to paths 1 in. long, and would refer him to Peek's Dielectric Phenomena, Table LXIV for instance. A third effect is undoubtedly the tangential or longitudinal stress in the fibrous insulation and particularly along the dividing surface between the fibrous insulation and the oil, which stress is a function of the slope of the sleeve as emphasized by Mr. Oesterreicher in his discussion.

It is of course very necessary that the correct slope should be used in the tapering portion of a joint or terminal, and I brought out the importance of this in the text immediately following Table II. Theoretically, I agree with Mr. Oesterreicher that the slope should not be a straight line. Practically, however, with the small angles used, there seems no sufficient justification for using other than the straight-line construction for the slope. Mr. Oesterreicher questioned my statement that the diameter of the sleeve was of no consequence. Possibly he has forgotten that the entire joint is shielded inside by a metal coating of the cylindrical portion and by the tapering tinfoil at the ends. That is, the joint is completely shielded inside, and the outer sleeve is merely a mechanical covering, and its shape and dimensions have no electrical function.

I heartily agree with all the remarks about joint-testing standardization. It is usually possible to obtain a joint or to design a joint, which will stand any given test up to the demands of present cable practise, if the correct design principles are used. One of the most difficult questions for a given voltage however is to determine what the proper tests should be.

Mr. Del Mar's remarks on internal pressures are much to the point. I might add that some of our tests on joints were made with the joints as cold as minus 10 deg. cent. and up to about 20 deg. cent. without observing any effects on the strength.

Mr. Rakestraw tells us that in their design of joint, they are able to add 50,000 volts breakdown strength by abandoning stepped insulation and developing their enlarged connector with undercut insulation. He unfortunately does not mention whether the increase of 50,000 volts was in short-time strength or in long-time strength, and there is a vast difference in significance between the two. He also indicates that a certain number of steps seems better than either a greater or less number. It is difficult to generalize on such questions, and all that can usually be stated is that a specific number of steps or a particular type of connector is better with a certain design of joint. I formerly shared Mr. Rakestraw's belief that a certain number of steps was the best. While not desiring to generalize too much myself, I believe now that the greater the number of steps the stronger the joint, but that the percentage gain is so slight after a certain number of steps have been chosen as not to justify the increased labor of cutting more steps. In regard to the enlarged connector and undercut insulation, while this construction has increased the strength of the type of joint Mr. Rakestraw was discussing, it distinctly is not as effective as the stepped insulation with our type of joint, as determined by practical experience. I do not believe that it is safe to state that any one construction of connector is better than any other, but merely that certain types are best for certain designs of joints, and the only criterion is the strength of the completed joint, which in our case is indicated in the tables given.

I am glad that Mr. Eby has commented on their success with applying tapes by hand, as opposed to the use of wide paper. I may state to Mr. Eby that my paper was actually written before the development of the joint to which he refers, and that possibly my statements were a little too emphatic. In general, however, the application of wide paper is inherently quicker than that of narrow tape. For instance, if the applied insulation is to be 3 ft. long and tape 1 in. wide is to be used, the roll of tape must be wrapped about 36 times around the joint to form one layer of insulation, while one turn of wide paper will do the equivalent amount of work I am sure that we all agree with Mr. Eby in his remarks about oil for filling joints, and the beneficial effect of such oil upon the insulation of the high-voltage cable which is being jointed.

Mr. Peterson questions the novelty of the joint, and possibly I was not clear enough in emphasizing exactly what new points were presented in the paper. Stepped joints and electrostatic shields at the ends of a joint are of course known, but I believe that a stepped joint with wide paper in the steps (particularly a stepped joint with wide paper cut to fit the steps at the moment of application), and shields formed by metal previously applied to sheets of insulation in a predetermined slope are new developments. In addition, I might include the machine-wrapping of wide paper, which process insulates from the connector to the outside and automatically forms the electrostatic shields.

As a matter of general interest, I might add that eight of these joints have gone into service at 132,000 volts, three-phase, within the 2½ months since the presentation of the paper, on February 24 in an experimental 132-kv. line, and have operated without incident to the present time.

OIL BREAKDOWN AT LARGE SPACINGS[1]

(Miner)

New York, N. Y., February 9, 1927

O. R. Schurig: The problem attacked by Mr. Miner, *i. e.*, that of oil breakdown at large spacings of from 1 in. to 15 in. and more, and when subjected to sustained voltage stresses, is of real importance to engineers because (1) the gaps in high-voltage apparatus are commonly of the order of 1 in. or more and (2) because the voltage stresses for a good part of the time are of a sustained nature. The designers of oil-immersed transformers and circuit breakers must therefore take into account the behavior of oils between widely spaced gaps and under sustained voltage stresses. Mr. Miner's data represent an advance of knowledge in this field.

At the same time, however, designers must also provide for sufficient dielectric strength at small spacings and under suddenly applied voltages. In oil circuit breakers, for instance, the sudden formation of ionized gases during circuit interruption has virtually the effect of shortening the clearances, for a few instants, between live and grounded paths of the oil vessel. Moreover, the temporary stresses acting on the oil at such times will often be higher than those occurring during normal operation under sustained voltages. Hence, in the design of such apparatus and in the selection of oils, engineers will need to take into account the dielectric strength of small gaps and for sudden voltages as well.

The second item that I wish to discuss is the point stressed by Mr. Miner that the results of short-time tests[2] are hopelessly erratic. I believe that he does not intend to have that statement apply to tests properly conducted with small gaps, such as the customary 0.1-in. gap between 1-in. disks. If reasonable care is taken in cleaning and drying the electrodes before the test, results of good reliability are obtained.

The following table gives the short-time breakdown voltages with a 0.1-in. gap of three samples of oil of various degrees of purity.

Sample No.	Breakdown voltage kv.	Ave.	Probable error of ave. in kv.
1	51, 59, 59, 58, 62, 62, 48, 48, 47, 54	55	1.7
2	10, 40, 48, 5, 23, 5, 22, 12, 12, 21	20	3.7
3	30, 28, 31, 24, 29, 30, 22, 22, 35, 29	28	1.1

The breakdown values of samples No. 1 and 2 are taken from the test values from which the curve of the accompanying Fig. 1 (which will be discussed later) has been plotted, sample

1. A. I. E. E. Journal, April, 1927, p. 336.

2. Meaning tests in which the voltage is raised fairly rapidly from zero to the point of breakdown, at a rate of, say, 3000 volts per sec.

No. 1 is the oil sample before being mixed with water and sample No. 2 is the same oil after being mixed with water and standing 1.8 days. Sample No. 3 is a transformer oil containing fibrous particles which were purposely mixed in the oil. By the "probable error," as given in the last column of the table, is meant an error of such a value that the probability of having a

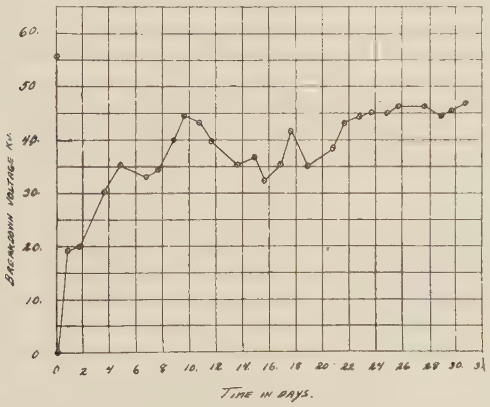

FIG. 1—THE RATE OF SETTLING OF WATER IN A TRANSFORMER OIL AS INDICATED BY THE BREAKDOWN VOLTAGE OF A 0.1-IN. GAP BETWEEN 1-IN. FLAT DISK ELECTRODES.

3 per cent of distilled water mixed in 1.5 liters of new oil by shaking for 4 min.
Number of breakdowns per point 10.
Rate of increase of voltage 3000 volts per sec.
Oil at room temperature, 20 deg. cent.
Breakdown voltage of oil before mixing with water; 55 kv.

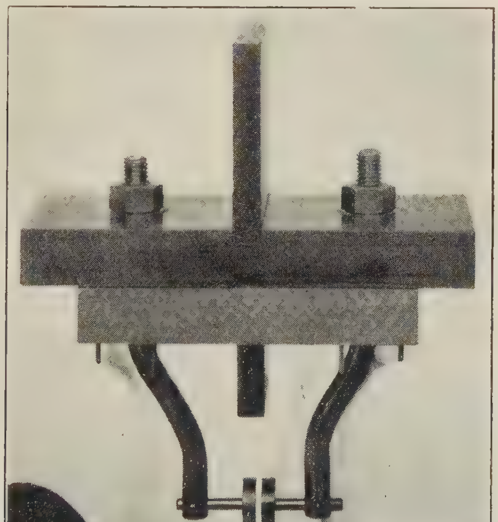

FIG. 2—ELECTRODES AND MOUNTING; 1-IN. DIAMETER BRASS DISKS, WITH 0.1-IN. GAP.

The electrodes were made for placing on a glass jar 3 in. by 5 in. by 7 in. high.

greater error is just equal to that of having a lesser error. This probable error is calculated from

$$P.\ E. = \frac{0.85\ a.\ d.^*}{\sqrt{N - 1}}$$

where *a. d.* is the average deviation of the breakdown values from the mean and *N* is the number of breakdown values, in this case 10.

The third point that I wish to discuss refers to the effect of water on the dielectric strength of oils. Mr. Miner has presented data on the dielectric strength of oil containing water for wide gaps. I wish to outline the results obtained on the dielectric strength of oils mixed with finely divided particles of water.

The tests in question, made with some of the customary high-grade mineral insulating oils, tested with a 0.1-in. gap between 1-in. plane disk electrodes, showed that a thoroughly shaken up mixture of the oil with, say, 3 per cent of water gave initially less than 5 kv. dielectric strength, *i. e.*, when tested immediately after mixing, as is well known. After standing, however, the mixture began to separate with a consequent rising of the dielectric strength until after several days, the water had settled to the bottom, the oil had cleared up and had *regained a relatively high dielectric strength although there was a layer of water under the oil and in contact with it.* This result was consistently repeated in the absence of impurities other than water.

A typical curve is given in Fig. 1, showing the dielectric strength recovery of an oil-and-water mixture allowed to stand after throughly shaking up.

Fig. 2 is an illustration of the electrodes and their support.

The tests were made at Schenectady, as part of a research program aimed at determining the effects of various factors, such as water, carbon, heat, time, exposure to air, fibers, electric field, metals, etc., on the dielectric strength of circuit breaker and transformer oils.

V. M. Montsinger: Generally the breakdown voltage of oil is so erratic that few, if any, investigators have felt like trying to express it by a mathematical formula. The answer to this appears to be, as pointed out by Mr. Miner, that too small spacings have been used, spacings below the critical breakdown value.

I was interested to see that the author finds that for certain conditions, the dielectric strength varies as the spacing raised to the 0.7 power. For design purposes we have used in transformer work a similar law of strength varying as the $^2/_3$ power of the spacing or distance between electrodes. This expression seems to be one of nature's dielectric laws. Not only oil but solid dielectrics with similar electrodes follow somewhat the same law. However, if the electrodes are large flat planes with edges having large radii and the field is approximately uniform, the strength is practically a linear function of the spacing for both oil and solids. In other words, the strength varies almost directly with the spacing. This fact should be kept clearly in mind in generalizing on the laws of dielectrics.

The question of why the difference in the laws suggests itself naturally. The explanation for this is probably about as follows: When the electrodes are of such a shape as to produce a distorted field, this distortion becomes more and more pronounced as the spacing increases. Thus, for example, if the electrodes are small rods or spheres, at small spacings the dielectric field causing breakdown is more nearly uniform than when the spacing is increased. Finally, when the distance becomes great enough, the distortion becomes so great that the electrodes act like needle points, even though they may be many times larger. Mr. Miner's explanation of why they act like needle points above the critical spacing, by the ionization theory, seems a logical one.

The main points which I wish to emphasize are (1), that for uniform dielectric fields the strength of oil is approximately a linear function of the spacing and (2), for distorted fields the dielectric strength varies approximately as the $^2/_3$ power of the spacing or 0.7, as Mr. Miner states in his formulas. I prefer to use $^2/_3$ because it is a value very easy to remember. Roughly speaking, this means that if the spacing in oil is trebled, the strength is doubled, or to be more correct is increased 2.08 times. As regards uniform fields, in practise this condition is seldom, if ever, found. Consequently the $^2/_3$ power law is more nearly applicable than the first power or linear function law.

R. J. Wiseman: In regard to Mr. Miner's paper, where he refers to the effect of water or moisture in his oil, I wonder

*Precision of Measurements and Gaphic Methods by H. M. Goodwin, McGraw-Hill Book Co.

if he has taken into account the possibility that under high stress, with wide spacings, there is a certain attraction of the moisture toward the surface of the conductor, causing an increase in the diameter of that conductor which will decrease the stress temporarily until breakdown occurs. I think that is partially the explanation of why we are getting a higher breakdown voltage with a wide spacing and a large amount of moisture present.

I was very glad to see that Mr. Miner has tackled this problem from the point of view of ionization. We all know pretty definitely ionization occurs in gases. Some of us have a pretty definite idea of ionization in solids. This is a sort of connecting link between the two, and I hope further work along this line will be carried on.

Mr. Roper suggested that we find a new way of testing cables for their quality. We are all interested in cables and want to know how we can determine what is a good cable and what is not. We make a good many tests today in order to pick out good cable. Another test means additional work on the part of the cable manufacturer; it is costly to both the purchaser and manufacturer. Apparently the tests today are not giving us what we want. When the cable leaves the factory, as far as we know, it is 100 per cent perfect. When it gets into service, it apparently breaks down. Is it a question entirely of tests in the factory, or is it also a question of operation in the field?

I hope we shall be able to find a new test that will help us to determine high-quality cable, but if we are going to have additional tests, let us drop some of the tests we now make which are unsatisfactory, rather than simply add one or more new tests to the number we now have.

F. W. Peek: Those of us who have had experience with oil as used in apparatus know that it is not only the most reliable and consistent insulation but also one of the best. However, oil is very erratic under test, and I wish to point out a few of the reasons.

As used in apparatus, the oil spaces are always divided by barriers of solid insulation. These barriers change oil from an unreliable to the most reliable insulation by preventing lining up of conducting particles. Some of the principal causes of erratic changes in the breakdown voltage of oil are occluded gases and foreign particles such as moisture or fibrous materials. Foreign particles may line up in the electrostatic fields. In the case of large electrodes such as plane surfaces the lines of force are straight lines. In such a field particles readily form chains from electrode to electrode along these lines. A short gap with large electrodes has very high dielectric strength for very good oil but very low strength for poor oil. The percentage change is thus very great for such a field. Impurities are easily detected by such a gap. As the spacing is increased the chance of lining up becomes less.

The other extreme in electrodes is the needle gap. The lines of force are curved, and are very concentrated at the points or at the electrodes. Any particles in this field will tend to go toward the electrodes to make them larger and store a greater amount of energy. Those that strike the electrodes will be charged to the same potential and immediately repelled or shot away. There is no tendency to line up. In fact this action purifies the oil between the terminals. So, with a needle type of gap there will be very little difference in dielectric strength, whether the oil is very good or very bad. This is especially so if the spacing is large.

The same effect occurs with spheres or other forms of electrodes at large spacings. I had an experimental apparatus which showed this very nicely. It consisted of a test tube filled with a light-colored oil in which an emulsion was made with colored water. A wire was extended through a cork and down the center of the tube. About two-thirds of the lower part of the test tube was then placed in a jar of clear water. The wire acted as one electrode, the transparent water as the other.

As soon as voltage was applied the oil immediately cleared up. An examination showed the particles of colored water around the inner surface of the test tube as well as at the bottom of the tube. The water particles had been attracted to the inner electrode and then repelled to the opposite side where, because of the less dense field, they gradually settled down to the bottom.

F. M. Clark: The hope has been expressed by one of the previous speakers that continued research will eventually result in a thorough understanding of the dielectric phenomena occurring in oils which are subjected to high or low voltage stress.

The average theorist, in considering the insulation problem, becomes very largely discouraged as soon as he starts to look up the previous literature history. Solids themselves are bad enough and show a very erratic nature; oils we know are blamed much more. However, it is probably true that a large part of the blame, instead of being placed upon the insulation, should be placed upon the various investigators who have not carefully considered the physical and chemical characteristics of the materials tested. Oils for example must be considered as chemical mixtures, the constituents of which are variable to a large degree. To understand thoroughly the behavior of a mixture we must know something of the behavior of each of its constituents. This is a difficult problem involving much fundamental research. If, however, we work on "commercial grade" oil such as Mr. Miner has carefully stated he used in his experiments, we have increased the difficulties of the problem by increasing the number of constituents of the mixture on which we are working. And worse still, the added constituents are variable in amount from day to day since the chief "foreign" material in commercial-grade oil consists of water and fibrous material over which we have ordinarily but little control. It may be claimed that if the dielectric strength is maintained, the water content may be considered negligible or fixed. Yet we have some evidence that wet oil may have high dielectric strength if properly tested.

In the same way, much of the difficulty besetting the solution of insulating phenomena, is to some extent increased by broad conclusions drawn from limited data. Thus Mr. Miner states in his paper that solids and liquid insulators show a non-linear dielectric strength-thickness relation. If, by this, Mr. Miner means oiled solids, tested with small electrodes or oils tested with small electrodes, he is largely correct. Yet it has been shown in a previous publication (The Dielectric Strength-Thickness Relation in Fibrous Insulation—*G. E. Review*, Vol. 28, page 286 for 1925) by V. M. Montsinger and myself that this is very largely a function of the testing method for oiled solids at least. Thus with large electrodes, oiled paper shows a linear strength-thickness relation. Moreover, untreated papers also show a dielectric strength very largely independent of thickness. In certain unpublished researches which we have carried out at Pittsfield, it appears that oils behave likewise and show a linear strength-thickness relation when large electrodes are used for the test. We hope to present this research to the Institute at a later date.

Mr. Miner advocates a long-time test in preference to the standard, rapidly applied test on oils. A more reliable test result is claimed. With carefully prepared oils, I believe that considerable of the erratic nature of oil breakdown might be eliminated. Unless care is taken, long-time tests merely indicate the time and voltage relation necessary to "suck" sufficient impurities into the field to bridge the electrodes. The test becomes one for impurities (such as fibres) rather than a test on the oil itself. This is illustrated clearly by the researches detailed in the Seimen's *Zeitschrift* for January, 1925, page 29. The short-time test comes nearer being a test on the oil itself. The fact that benzol gives more reliable test results is merely an indication of the effect of purity. With benzol, a degree of freedom from foreign substances can be obtained which cannot be approached in oil unless extreme care is taken in preparing the sample.

Another contributing cause to the confusion at present existing in the study of dielectric phenomena is the lack of proper definition of the experimental conditions. The dielectric strength-thickness relation for oil can very largely be upset by varying the position of the testing electrodes. With 10-in. plane electrodes, the test results are largely dependent on whether the electrode face is vertical or horizontal.

In the consideration of insulation data from the standpoint of fundamental theory, we must be very careful in accepting results based on ordinary commercial-grade material. In the same way, the designing engineer must be very careful in accepting data based on material which appears to approximate his operating conditions. Thus the dielectric strength of oil can be made low by a variety of methods some of which may or may not be applicable to his special machine. It is very difficult and dangerous to attempt to apply laboratory oil data to the explanation of fundamental theory, or even to the design of electrical machinery, if the tests involved concern foreign material dissolved or suspended in the oil, rather than tests on the oil itself.

Jacob Katzman (communicated after adjournment): Mr. Miner circumvents the difficulty he encountered in the erratic action of oil for short-time tests by lengthening the testing time, and apparently the effect of the time factor on the breakdown voltage is not taken into account in the final conclusions. His results for 10-min. hold tests are obviously more consistent than his instantaneous results, consistent enough to be mathematically expressed. It seems to me that this subterfuge may seriously mislead us if we are not on guard. Mr. Miner correctly recognized, (1), that the greatest variations obtained occur at small spacings, and, (2) as shown under General Remarks on Test Results, that at short spacings, the breakdown voltage decreases with increased time of application of voltage. Is not the second phenomenon the reason for the first? Is it not likely that that condition which would really give a comparatively high breakdown for instantaneous voltage application, is brought to within the average breakdown by this extension of time?

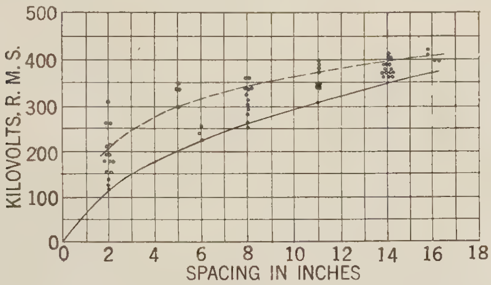

Fig. 3—Combined Curves of Breakdown Voltages for One-Inch Diameter Rods

Solid curve is from Fig. 8 of original paper and represents breakdown voltages for ten-minute hold.

Dash curve and circles are from Fig. 4 of original paper and is for instantaneous breakdown voltages.

The fallacy in ignoring the time effect is more readily appreciated when considering the behavior of a solid dielectric, such as oil-impregnated paper, under similar conditions. A number of apparently uniform dielectrics when given an instantaneous breakdown test, show very erratic results, perhaps more so than oil. Some will break down at voltages two or more times higher than others. However, every dielectric has a definite life at some particular voltage, and, samples of one kind of dielectric show no more variable life than is shown by the instantaneous breakdown voltages. But, as is well known, the life of the dielectric varies inversely as the seventh power of voltage, and, hence at the high testing voltages, the life is rather small. If, therefore, instead of several seconds of voltage application, ten minutes is used, or, better still, five times ten minutes, then, of course, materials having variations of strength of 10 or even 20 to 1 will breakdown within that length of time, the weakest samples will break first, and the others will follow in the order of their strength. In other words even though all their variations in strength are still existent, the time was made long enough so that the life of almost all the samples will be spent at the voltage applied. We have, therefore, only apparently succeeded in obtaining uniform results by disregarding the important element of time.

That this is actually the case also with the oil can be seen from Mr. Miner's own findings. He finds that short-spacing breakdown will occur at smaller voltages if applied for longer time. At these smaller spacings, time is, therefore, an important factor. Now, by plotting Mr. Miner's curve of Fig. 8 on the same graph sheet with his curve of Fig. 4 retaining at the same time all the points showing the large variations at instantaneous breakdown we get the curve shown in the accompanying Fig. 3. From this combined figure it becomes immediately obvious that for the 10-min. hold, he used in every case a voltage lower or equal to the lowest voltage obtained at instantaneous breakdown, and by extending the time to five times ten minutes, succeeded in breaking down the oil that might otherwise show the highest instantaneous breakdown voltage.

The whole process seems to me to be akin to throwing away a micrometer because it shows up inaccuracies, and using instead a carpenter's rule to avoid detection of these inaccuracies. For it is evident that by making a time test the properties of the oil are not changed, and its molecular arrangement or arrangement of particles of impurities is not affected or controlled thereby. The varying instantaneous voltage breakdowns are merely replaced by varying lengths of time of breakdown at time-hold tests.

From the same combined curves too, it is hard to see how Mr. Miner could deduce that at large spacings length of time of voltage application does not affect voltage breakdown. Between instantaneous and 10-min. hold a difference of 10 per cent is seen at 16-in. spacing. Of course this is not as large as the 100 per cent at 2-in. spacing. It should be noted, too, that to get these changes, there was a change of length of time from a few seconds to many minutes or probably a ratio varying from 100-to-1 to 1000-to-1.

It is interesting to note also that at the larger spacings, where time is not as important an element, his results show practically the same variation for long as for short-time tests.

D. F. Miner: I was very much interested in Mr. Schurig's remarks about the erratic results obtained on large gaps compared to small gaps. It seems that we must define what we mean by "large" or "small." We found a great deal of variation in tests obtained at 2-in. spacing, which we in our tests thought was small. But if you call a gap of 0.1 in. or 0.2 in. small, then I certainly agree with him. If we had to put up with the divergence of results on small gaps in our standard oil-test cup that we find on real large gaps of several inches, we certainly would not complete very many standard oil tests per day.

There seems to be a good deal in the literature and in the data presented by Mr. Schurig as to the effect of large quantities of water on oil. In other words, if it doesn't improve the quality of oil, at least it doesn't harm it under certain conditions, but that would not be a good reason for recommending to operating people: "Dump water into the oil in your apparatus." The harm of the water in the oil is not in the decrease of the oil strength itself, but the effect on the insulation; it gets on the insulating surfaces and leads to creepage breakdowns.

I was very much gratified to have the confirmation of test results by Mr. Montsinger on breakdown formula for point gaps. I agree with him that the two-thirds power of separation is a much better figure to remember than 0.7. It appears that large-curvature electrodes, at large spacings, behave almost like needle gaps, as far as the actual voltage breakdown is concerned, but of course with sharp points or small electrodes, corona occurs at an earlier voltage. So that the reason for increasing the

diameter of high-potential parts is to suppress ionization and corona rather than to increase the total breakdown voltage.

In connection with the argument as to whether tests should be made on commercial grades of dielectrics, such as oil, or whether we should purify our oil to the greatest possible extent and obtain data on that, there is a divergence of opinion. In this particular investigation we were interested in information that a design engineer could use. Now, it does not help him much to know that a certain gap once stood 300 kv. but the next time it might go down to 150. The 300-kv. value is not going to be of use. He has to design for minimum breakdowns, with a factor of safety then added to that. So that theoretical considerations in the true dielectric strength of oil did not enter into this problem. It was an engineering problem which was part of a series of tests on other electrodes besides spherical, that is, actual shapes occurring in apparatus, to develop design information.

SPACE CHARGE AND CURRENT IN ALTERNATING CORONA[1]

(Willis)

New York, N. Y., February 9, 1927

Joseph Slepian: One thing that Mr. Willis brings out and which is worth emphasizing is that the beginning of corona is not the point where ionization by collision begins. This is important because very frequently in the past it has been assumed that the beginning of ionization by collision is also the beginning of breakdown or of corona under various conditions. Mr. Willis has shown by his experiments here that the corona comes at a higher gradient than that at which appreciable ionization by collision occurs and that corona sets in when a sufficiently great cumulative reaction takes place between the ionization produced by collisions of the negative ions and that produced by collisions of the positive ions. Hence the gradient at which the corona begins is not a constant of the gas but also depends upon the geometrical configuration of the electrodes; that is, it depends also upon the radius of the wire and the distance to the other electrode.

Alexander Nyman: I should very much like to see this work extended to include operation at high frequency.

Probably many people are familiar with the fact that at high frequency the corona begins to appear at much lower voltage than

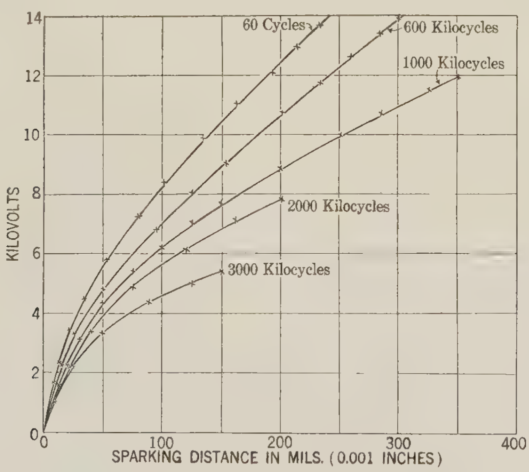

Fig. 1—Two-c. m. Sphere-Gap Sparking Voltage at Various Frequencies

at 60 cycles; in fact, perhaps two or three times lower at frequencies as high as 1,000,000 cycles. At frequencies as high as 5,000,000 or 10,000,000 cycles, corona begins even at lower voltages than this; it is possible to observe a corona on sharp points at 1000 or 1500 volts. This fact became apparent in the first place during the measurement of voltage on static condensers and on insulators for condensers for use on power transmitting stations. A sphere-gap calibrated at high frequency showed values as illustrated in the accompanying figure, from which it is evident that the sparking voltage at 1,000,000 or 2,000,000 cycles is considerably lower than at 60 cycles. At 10,000,000 cycles these voltages are lower yet.

Now, it is evident that the discharge between sphere-gaps is not of the nature of corona, but the reduction between the sphere-gaps brought to the attention a similar reduction of discharge voltage between sharp points and it was then even more conspicuous.

With the spacing of ½ in. and a frequency of 10,000,000 cycles, a sparking distance of 4000 or 5000 volts is quite usual between edges which are not strictly sharp. Of course, with sharper edges this voltage is considerably lower. The question will arise "How do we know that this is a correct voltage measurement?" The process to ascertain this fact is rather lengthy, but consists in general of the following:

A static condenser, which remains constant at different frequencies, and a measurement of current and frequency gives a measurement of voltage.

The measurement of current may be again in doubt, but can be assured by a proper design of an ammeter, suitable for this specific purpose.

W. A. Del Mar: On the third page of Mr. Willis' paper there is this statement: "The results of the corona ionization are electrons and charged nitrogen molecules. The absence of the oxygen spectrum indicates that the nitrogen alone is ionized, or that the oxygen does not play any appreciable part in the corona ionization." On the sixteenth page there is something which appears to be contradictory. Under "Summary," paragraph one it says: "The electrons, even in the high electric field around corona wires, almost immediately attach themselves to molecules, (probably of water vapor or oxygen), forming ions as seen from the mobility below." Oxygen is here mentioned as one of the types of ions, whereas in the preceding paragraph it is said to have practically no part. I should appreciate an explanation.

H. J. Ryan and J. S. Carroll (communicated after adjournment): Three papers have been presented to the Institute, heretofore, that deal largely with the space charges which surround conductors in alternating corona [a,b,c]. These papers are not mentioned in the bibliography given at the end of the paper and no reference is made to their conclusions, which are quite different from those here presented. The facts presented in the preceeding papers were obtained by quantitative studies of the *whole* space charge that surrounds a conductor in corona due to high voltages at low frequencies,—generally 60 cycles. The studies reported in the papers presented at Seattle, [b] 1925, and Salt Lake City, [c] 1926, included the cyclic time element and the radial positions of the space charges.

The electrodynamic behavior of the ions in the alternating corona cycle is far too complex and too little understood, as yet, to enable anyone to formulate a theory of the space charge such as attempted in this paper. The author is apparently convinced that the integrity of his theory is ample to warrant him in setting forth the complete *quantitative* behavior of the space charge from *qualitative* observations of diffuse remnants of alternating space charges with the determinations of the radial positions incomplete and the cyclic time elements wholly omitted.

We submit that one cannot inform himself reliably about these space charges by that sort of procedure and that he certainly

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1. A. I. E. E. Journal, March, 1927, p. 272.

a. H. J. Ryan and H. H. Henline. *The Hysteresis Character of Corona Formation.* A. I. E. E. Trans. Vol. 43, 1924, p. 1118.

b. C. T. Hesselmeyer and J. K. Kostko. *On the Nature of Corona Loss.* A. I. E. E. Trans., Vol. 44, 1925. p. 1016.

c. J. S. Carroll and H. J. Ryan. *The Space Charge that Surrounds a Conductor in Corona at 60 Cycles.* A. I. E. E. Journal, Vol. 45, p. 1136, Nov. 1926.

cannot help others. Surely knowledge of all facts that it is possible to obtain must come first; the facts must be studied thoroughly to develop an understanding of their mutual relation and then only can a theory be formulated and put forth to assist others to acquire, with economic effort, such understanding.

Dependable knowledge as to these space charges is of undoubted importance in high-voltage engineering. We regret that Mr. Willis has made it so difficult for us to join in a more hearty welcome to him with his results, as a worker in this field in which we hope we can all continue to work unremittingly. We earnestly trust that we will soon be able to resolve our differences with understanding, so that we can present the facts about these space charges, without confusion, to the membership of the Institute.

C. H. Willis: I appreciate Dr. Slepian's emphasis of the fact that the corona gradient is not the beginning of ionization by collision. In ionization by collision we are measuring average effects, but the probability of ionization at any particular collision between an ion and a molecule depends on the actual free path which the ion has just traversed and also on the type of collision. The saturation current in the gas increases as the voltage rises and the explanation of this increase is ionization by collision. We cannot, however, pick any particular voltage as the point where ionization by collision begins.

In corona, the current rises abruptly at a certain voltage. The explanation is that at this voltage the ionization has become cumulative to such an extent that it would lead to a short circuit, but for the action of the space charge.

Mr. Nyman speaks of the lowering of the voltage at high frequency. His remarks were quite interesting to me. The only work I know of in this regard is the work by Gorton and Whitehead, in which they found the corona gradient to be affected to about two or three per cent at frequencies up to 3600 cycles per second. I should be very much interested in seeing further work if it has been published.

In regard to Mr. Del Mar's question, I believe my statement was that the nitrogen played the main role in ionization by collision. We have in the air a mixture of N_2 molecules and O_2 molecules. There are, of course, two ways in which we may produce ionization. We can dissociate the molecules into N plus and N minus. This would give a line spectrum. Therefore, this is not the form of ionization which occurs in corona, nor does that occur except at very much higher gradients than the corona gradient. But the band spectrum indicates that the N_2 molecule breaks up into a positively charged N_2 molecule and an electron. We must remember that the electron has a mass of $^1/_{18}$ hundredth of the hydrogen molecule and therefore, is very much smaller than a nitrogen molecule. The probable mobility of the nitrogen molecule is around 10 cm./sec. per volt/cm. I had expected in this work to find that the negative space charge would have a very high mobility and would penetrate the air to a very much greater distance than the positive space charge. To my surprise, I found that the two charges penetrated to practically the same distance, and the conclusion which follows is that the electron attaches itself to a molecule very quickly forming an ion.

The nitrogen molecule is ionized and the electron then attaches itself either to a water or oxygen molecule to produce an ionic carrier rather than an electronic carrier. The reason that I conclude that the electron attaches to water vapor or oxygen is the fact that water vapor and oxygen have a very much higher electron affinity than nitrogen. We would expect that the nitrogen would not attract the electrons, from the work done by physicists.

The author wishes to apologize for the omission of the paper by Messrs Ryan and Henline, from his bibliography. The bibliography however is by no means complete, as only those papers are given which seemed to have a direct bearing on our work. The other papers mentioned by Messrs. Ryan and Carroll were published after this work was planned and the bibliography prepared.

We feel that the criticism of Messrs. Ryan and Carroll that our work was qualitative is hardly justified. The method of determining the total space charge by measuring the rectified current is probably the most accurate method, and is certainly not subject to the very serious criticisms which may be made against the other methods which have been employed. (*i. e.*, that these methods either limit the space charge or distort the field or both.)

We also feel that any serious criticism of our generalizations in regard to the space charge, which are used in developing the expression for the average value of the corona current, should include a demonstration of the inaccuracy of the expression for the corona current.

A NEW ELECTRONIC RECTIFIER[1]

(Grondahl and Geiger)

New York, N. Y., February 11, 1927

G. W. Janson: Schemes such as that shown in Fig. 14 have been tried at various times by communication engineers, in their efforts to increase the output of telegraph circuits. The possibilities of these arrangements have, however, been generally limited by factors other than the effectiveness of available rectifying means. However, there are probably many other valuable uses for a rectifying element having the excellent characteristics described in this paper.

Several questions have occurred to me which would be of interest to those seeking to adapt the element to purposes other than converting an a-c. supply to a d-c. supply.

What is the maximum voltage per element which may be applied before the rectifier passes a-c.? Are the characteristics of the rectifier permanently changed after that maximum voltage has been applied? Has the rectifier been used for application to loads of varying resistance and are the voltages under such conditions affected differently from those shown in the curves? Are there any polarization effects?

Another question that might be of importance is, whether any time lag exists between the application of a potential to the flowing of direct current. I wondered, for example, whether the resistance ratio curves and the data on resistance at various voltages were determined by d-c. methods or by a-c. methods. If by a-c. methods, would those ratios be different for the steady d-c. state?

A. G. Oehler: When a rectifier is made of a number of elements connected in series, does the voltage or the power rectified in each unit divide up equally over all of the elements? What factors of design or what inherent characteristics limit the voltage which can be rectified by this rectifier?

George Crisson: The system of signaling described by Messrs. Grondahl and Geiger is of interest because it accomplishes duplex operation by very simple means which do not involve the problem of line balance.

Certain effects occur in this system, however, which are not encountered in the telegraph systems now in use. These effects, which are due to the fact that the velocity of propagation of a wave over a telegraph wire is not infinite, put definite limits on the distance over which signaling can be carried on without the use of repeaters.

No reason is seen why the system should not operate satisfactorily when the length of the line is a small fraction of the wavelength. The operation of any key will cause changes in the strength of the current in the corresponding instrument at the other end of the line so that signals can readily be sent but will not affect the instruments in the second channel.

As the distance from the generator to the end of the circuit increases, the behavior of the system becomes more complex.

1. A. I. E. E. Journal, March, 1927, p. 215.

Operating a key has less effect on the corresponding instrument at the far end, and begins to produce changes in the current of the distant instrument in the second channel. This effect is due entirely to the fact that a finite time is required for a wave to travel from the generator to the key and back. It is quite distinct from the weakening of signals due to losses in the line.

The system would become inoperable when the distance from the alternator to the key has increased to one-eighth of the wavelength, or the total length of the line has reached one-quarter of the wavelength, assuming that the alternator is located at the middle.

Assuming that a frequency of at least 200 cycles would be required to avoid operating difficulties caused by the periodic nature of the current, the greatest length of line workable by this system without repeaters would be about 200 mi. for non-load open-wire lines, and a much shorter distance, in the neighborhood of 50 mi. for non-loaded circuits in cable. Practically, the lengths would have to be still less to allow for a safe operating margin and for various factors not considered in this simple treatment.

This system could not be applied to composited lines without modifying the compositing apparatus, which separates the telephone and telegraph currents at each end of the line in such a way as to encroach seriously upon the range of frequencies required for the telephone.

Of course, for classes of service permitting the use of a frequency lower than 200 cycles, the workable length of the line would be increased and the difficulty of applying the system to composited lines would be somewhat reduced.

Joseph Slepian: Four to five years ago in meditating about the usual thermionic rectifier—that is, a rectifier consisting of two electrodes in a high vacuum, one electrode heated—it occurred to me that probably other types of rectifiers were based upon essentially the same phenomenon; that is, the presence of three suitable materials, two metallic conducting electrodes and an intervening material. In the case of the thermionic rectifier the part of the intervening material is played by the vacuum.

In this combination of three materials, the electrodes are good conductors of electricity. The intervening vacuum by itself is an insulator but if electrons are somehow supplied to it, it becomes a good conductor. In other words, electrons can move freely in this vacuum if they are provided.

Now it seemed to me that it might be possible that other insulating materials than a high vacuum would have this same property, so that it might be possible to take two metals and put an insulating material in between them, this insulating material having insulating properties ordinarily not so much because it obstructed the flow of electrons but because it, itself, lacked free electrons. Now, if one of the electrodes was able to supply free electrons to the insulating material, and the other not, a rectifier would be obtained.

Of course if such a rectifier was to be practical, this insulating material would have to carry electrons rather freely, but the electrons would have to be supplied to it by the adjoining electrodes. It seemed, of course, that this intervening insulating material would have to be very thin, because you could not expect the electrons supplied to this material to move through it so freely as they will do in a vacuum. I thereupon set out to investigate the properties of thin insulating films between unlike electrodes, and for a little over two years I examined all kinds of combinations to get a very thin layer of insulating material.

I considered films formed chemically, and I got results that were frequently promising, and which led me to continue my work, but I never got anything that looked practical, or appeared to be worth following in greater detail.

Then I heard that a man from one of our neighboring companies, the Switch & Signal Co., had devised a rectifier consisting of copper and copper oxide for which great claims were made. I rather scoffed at it when I first heard about it, as I had already experimented with copper oxide. I had placed sheets of copper oxide against various metals and observed some rectification, but always the rectification was small and rather erratic.

A little time later some of these oxidized copper washers were supplied to me at the laboratory and I proceeded to test them, not expecting very much, and was quite amazed at the results. The rectification was steady to an unbelievable degree. After the experience of my two years work it seemed absolutely revolutionary. I had never seen or heard of anything like that in a rectifier of this type, and I looked into the rectifier more closely and was interested to find it had just the elements I was looking for. The ideal that I had been working for seemed to be realized in this rectifier that Mr. Grondahl had provided.

The rectifier consists of two bodies of metalically conducting material; namely, the copper and the oxide, and an intervening insulating layer. I have proven the existence of this layer between the oxide and the copper by making capacity measurements. The electrostatic capacity has such a magnitude as to indicate that the rectification takes place in a layer less than a 0.0001 cm. thick between the oxide and the copper.

It is most astonishing that a rectifying layer is obtained by such simple means as forming the oxide on the copper. It is also very astonishing that this rectifying layer is obtained only between the copper oxide and the metal on which it was formed. A piece of copper oxide by itself clamped against a piece of copper will give some rectification, but of an altogether different order and quality from that obtained where the oxide is formed on the copper itself.

B. O. Adkerson: Does the use of foils of other metal than lead, *e. g.*, aluminum and gold, change the resistance of the rectifier in the two directions? If the resistance is affected what is the amount of such change?

Fig. 6 in the paper shows the voltage-resistance characteristic curve of the rectifier between plus and minus 4 volts, and in reply to a previous discussion it was stated that about 30 volts was the maximum that one element would sustain. Does the resistance decrease continuously to zero as the negative potential is increased to this maximum? If it does not, what is the resistance at the point of discontinuity, *i. e.*, just before puncture occurs? When the rectifier is once rendered inoperative by exceeding the maximum voltage, will it automatically reform upon reducing the voltage, similar to an electrolytic rectifier, or is the element useless unless the copper washer is again oxidized?

Dr. Eccles' rectification theory, mentioned in Jolley's Alternating Current Rectification, indicated that rectification may occur at hot points of contact between or in the rectifying materials. Does the difference of potential across the rectifier, as determined by a rapid oscillograph, differ in any way from that across a pure resistance of equal ohmic value, when current is made and broken through it, *i. e.*, is there any evidence of a potential difference other than the $R\,I$ drop caused by the passage of the current?

Does the instantaneous response of the rectifier, mentioned in connection with wave-meter work, mean that the time required for the rectifier to reach a steady state is negligible, as considered from a practicable viewpoint, or that there is no perceptible change of current with time as determined by the oscillograph? If there is a change of current what is its approximate magnitude, is the current increasing or decreasing with time, and does the change occur in both directions through the rectifier?

L. O. Grondahl: The first question is with reference to maximum allowable voltage. The curve that gives the relation of the resistance in the high-resistance direction to the voltage shows that the resistance decreases with increasing voltage above two volts. We think of three volts in the high-resistance direction as being a normal counter-voltage for the rectifier to withstand. We are using them, however, in large units up to six volts with additional radiating surface. Within the limits mentioned it is only a question of carrying away the heat. When

higher voltages are used the losses in the high-resistance direction make it difficult to carry away the heat generated.

The resistance curves in the paper were taken with direct current. There is no polarization. There is a very slight change in current in the high-resistance direction, but it is immaterial and a large part of it is explainable as due to rise in temperature. It is not in the right direction to be caused by polarization. We have tried rather carefully to find a back current such as exists in a cell that polarizes. We have not been able to find anything of that kind.

That answers the question also in regard to the various loads. The effect of varying the load is illustrated in the efficiency curve. In that case the various loads were obtained by simply changing the load resistance.

There seems to be no tendency for one unit to pick up the load and carry it to the exclusion of the other units. It divides itself exactly in terms of the resistances of the elements. As far as our experiments show up to the present time the rectifier behaves as if it were a pure resistance phenomenon.

In some rectifiers, one rectifier will pick up the load for a little while, and then another rectifier in the series will take its place so that the load darts back and forth between the elements. That does not happen here at all. The load is evenly and steadily distributed.

We have a unit in the laboratory that we have been using for eight or ten months now, supplying one ampere at 1500 volts for oscillators. It has been a reliable supply without any maintenance.

On the question of forming first of all, there is no such phenomenon as forming in connection with the rectifier as far as we have been able to determine. When I say that it operates instantaneously, I mean that the time required for the current to start and for the final condition to be set up, as far as rectification is concerned, is as nearly instantaneous as you can get it with the inductance that you have in the circuit. It depends upon the inductance in the circuit rather than upon the characteristics of the rectifier. The rectifier is a resistance pure and simple as far as its observable qualities are concerned, certainly in operation.

The change in current in the high resistance direction that I mentioned is of very small value and probably has no practical importance at all. If you have 1 milliampere high-resistance current (for instance, back leak, when the alternating current is off and the battery is discharging through the rectifier) it may grow in a little while up to 1.5 milliampere. That is something we have not yet explained. However, there is no effect similar to forming.

You can put the rectifier on direct current in either direction for any length of time, take it off and put it on in the opposite direction, and it behaves just as though nothing had happened to it. You can start it on an a-c. circuit for rectifying after it has been rectifying for a long time, and it behaves exactly the same as when you start it after it has been resting for several weeks.

The question of hot spots: if you go up to very high voltages, say 30 or 40 volts per disk so that you puncture the surface, then you find that it acts like every other dielectric—it punctures in a spot—but we have not found any other evidence of the rectification taking place in spots, or the current being carried in spots.

The lead is used as a contact on the outer surface, because it is more impressionable than other metals that are easily obtainable and makes a lower resistance contact, a slightly lower resistance contact than we get, for instance, with aluminum foil. It is not quite as low as we get with gold foil. Gold foil is inconvenient to handle and sheet lead is practical. So we use the lead. All resistance changes are continuous.

J. F. Dreyer, Jr.: I should like to ask what degree of uniformity exists in these units? Do they vary much in resistance?

L. O. Grondahl: The degree of uniformity depends entirely upon how well we are able to make the manufacturing process uniform. For our train-control work, for instance, we hold them within 10 per cent on the output. That is, those are our specification limits.

H. J. Rosenberger: Four questions came to my mind: (1) What oxide of copper is used? (2) How do you put it there? (3) How do you keep it there? (4) Does it make any difference how thick that layer is?

L. O. Grondahl: The oxide is the cuprous oxide, the red oxide of copper. It is formed in a furnace and it is formed at such temperatures and under such conditions that it stays.

The thickness is of no consequence at all except, that the resistance increases with the thickness since the current has to flow through a thicker layer of oxide. Whether you have two mills of oxide or you have ten mills of oxide, you have identically the same kind of rectifier except for that increase in resistance in the low-resistance direction. The rectification takes place at the junction between the copper and the oxide or so close that we have not been able to distinguish it from the junction.

We have worked as low as 0.001 or 0.0015 in. of oxide, but for practical purposes we use 0.002 or 0.003 in.

D. E. Trucksess: I would like to know if there is any relation between the pressure on the contact and the output. I understand that after the rectifier has been operating for a while the output drops off. Can that output be increased by increasing the pressure?

L. O. Grondahl: The pressure applied seems to have an effect in that it reduces the contact resistance on the outer surface of the oxide. It is necessary to have a contact that is uniform over the whole surface as nearly as possible in order to get the low resistance.

As time goes on, there may be a slight reduction in pressure due to mechanical changes, which may be compensated for by tightening the bolt. As far as we know the pressure is important only in reducing contact resistance.

TELEGRAPH TRAFFIC ENGINEERING[1]

(Mason and Walbran)

New York, N. Y., February 11, 1927

J. H. Bell: There is one question I would like to ask Mr. Mason. On page three this statement occurs: "an experienced automatic operator works at between 55 and 60 words per minute while the average output per Morse operator is between 12 and 15 words per minute."

I question whether those two are comparable. My recollection is that it is much easier to operate a Morse system by hand at about 20 words per minute, and human nature being as it is, I rather think that the operator would prefer to operate about 20 words per minute rather than 12 or 15. I would like to know whether 55 to 60 words per minute is the output of the automatic operator?

H. Mason: The point is well taken. The way it is stated in the paper the figures are not literally comparable. I agree that, a Morse operator might work at 20 words as well or perhaps better than he would at 12, but our actual output is of the order of from 12 to 14 words per minute. In the case of the automatic operators 55 words per minute represents an average performance but not the output. The human nature feature comes in here. The operator is perforating against a machine. That machine is set to go at a given speed, generally about 55 words per minute. She must keep up with that machine or the auto control stops the transmission in a way evidencing her failure.

I am not prepared to say that the performance throughout the country is universally as high as 55, but individual operators can perforate at double that speed and we have no mechanisms which would take that rate of perforating. A recent figure shows the average output per Morse operator hour to be 28 equated messages, while that of an automatic operator is 62 equated messages. These figures reduce to approximately 15 words per minute and 32 words per minute respectively.

1. A. I. E. E. Journal, May 1927, p. 469.

J. H. Bell: Reference was made to the delivery of telegrams. Nothing was said about the messenger service. I would like to mention that in one of the British journals I read that they have started a new method of delivering telegrams. Instead of having the boys go out with each message that comes, they have divided the town into 25 or 30 separate routes. A boy leaves every five minutes from the telegraph office and he takes all the messages along one particular route. That makes for a slight increase in delay in delivery of some messages, but it brings the average delay much more uniform.

H. Mason: In the company which I represent the line of organization is not such that the messenger delivery problem comes under the control of the engineers for which reason I am not so well fitted as would be some other, to discuss this question. I do not think, however, that anywhere in our service is such a method as is suggested by Mr. Bell used.

We do have routes and send boys over them with messages just for those routes in-so-far as the delivery of night letters in the early morning is concerned, and also full-rate messages for which we have instructions, as we have in some cases, not to make delivery until the customer's office is open.

However, other than that, so far as I know, we do not at the present time indulge in the suggested practise but our full-rate meassages are taken out practically as they fall. That does not mean that the messenger boy always goes out with one, quite often he has two or three, but he is not definitely held until several come for that zone.

The matter of deliveries of the day letters may be held up. For instance, if it is several blocks from the office, the delivery clerk may very well hold up a day letter waiting for some preferred business to come along, and send it out with the same boy, but not as a policy.

A-C. ELEVATOR DRIVE[1]

(Thurston)

New York, N. Y., February 11, 1927

P. A. Lindemann: Unfortunately Mr. Thurston's paper does not give speed-time curves of the high-speed geared a-c. elevator. I should like to know the details of the stopping period of a fully loaded elevator having a car speed of 700 ft. per min. and the brake applied without appreciable slow down by the motor.

I rather expect an unevenly divided period of deceleration with too abrupt an ending due to the absence of dynamic braking, and too great a pressure on the shoes at low rotor speeds. I wonder if this assumption is correct?

It would also be interesting to know as to the thrust performance on a-c. elevators operating at car speeds of over 500 ft. per min.

To me it seems that the electrical efficiency would be higher, and cost of maintenance lower, were the compensator principle of control used, instead of the series resistance type which is liable to unbalance the phases due to loose and broken grids.

J. Lebovici: We would appreciate some description of the construction of the motor mentioned in this paper and would like to know in what respect it differs from a high-resistance Rotor squirrel-cage motor. We would appreciate having some speed-torque characteristics of the motor; also the slow-down characteristic.

We also would like to know if the motor is of two-speed, two-winding type.

We notice the statement that an elevator motor must allow torque characteristic changes at the installation. I would like to know how these changes could be made at the installation outside of varying, of course, the resistance in series with the motor stator.

We also notice that the number of switches or the number of magnets should be kept to a minimum. While we agree with this statement, we believe that the number of steps of acceleration should be as high as possible.

We would like to call attention to the development of a controller using an induction regulator for the purpose of applying a varying voltage in an infinite number of steps to the elevator motor. Such a control approaches the variable-voltage control of the d-c. motor.

E. B. Thurston: The question by Mr. Lindemann in regard to the stopping characteristics of a 700 ft. per min. a-c. elevator, if understood correctly, is a very important one. While he mentions the absence of dynamic braking, it is believed the information desired is the stopping characteristics, when the controller is moved quickly to the off position.

The apparatus covered by this paper is such that there is always automatic dynamic braking in slowing down, stopping or reversing from high speed independent of what the operator does.

The accompanying curve gives a typical test taken by an oscillograph. Curve *A* shows where the operator is slowing down the elevator by the motor only and running a short distance *C* on the slowest speed point and finally stopping at point *D* by the action of the brake.

Curve *B* is one showing the action when the operator quickly moves the car control switch to the off position.

Fig. 1

It is, of course, to be appreciated that by adjustment any rate of retardation desired can be obtained.

It is felt this feature of combined braking action is part of the development that made the a-c. elevator possible for higher speed service.

His next question in regard to the thrust performance on a-c. elevators. Experience has indicated that there is no difference in in the use of a-c. from that with d-c. power. If the question is in regard to the geared-type machine for the higher car speeds, we would cite as an illustration, a machine designed for either duty of 10,000-lb. capacity at 150 ft. per min. or for 2500-lb. capacity at 600 ft. per min. It is only necessary to change the gear ratio, to change from one to the other rating, and it surely is self-evident that the thrust loads, the tooth load and machine stresses are less on the 600 ft. per min. than on the 150 ft. per min. service.

Experience has proven that the wearing qualities of the gear in the higher speed service is much better.

The thrust load may be calculated by different methods and will be found that for full load lifting the 10,000-lb. service will have a thrust load of four times that of the 2500-lb. service, and for all allowable acceleration and retardation rates, the thrust loads of the 10,000-lb. service will be more than twice that of the 2500-lb. service.

Incidentally, it will be of interest to know that the 10,000-lb. service requires from 20 to 25 per cent greater motor horse power than that of the 2500-lb. service, even though the actual work done is the same. This is due to the much higher efficiency of the higher speed gear ratio, and is a fact well known in the gear art.

The question of compensator principle of control or resistance was raised and experience has indicated as yet that the resistance has worked out the best. It does not increase materially the

1. A. I. E. E. Journal, April, 1927, p. 321.

power consumption but does increase considerably the starting power factor, which is a very vital point in connection with power companies, especially where the lights and power are supplied from the same transformers.

The first question by J. Lebovici in regard to the motor characteristics is a very logical one, but it would be too long to go into the discussion of that at this time. It is hoped that in the next year or two a complete paper on motor development can be given.

His next question is in regard to the winding of the motor. The one to which this paper refers has a single stator, with two windings in the primary and with the high-resistance squirrel-cage rotor. However, as far as safe operation is concerned it is immaterial whether it is a single winding reconnected, or a double-type motor, providing it can be made to produce the other desirable characteristics mentioned in the paper.

His next question is in regard to a minimum number of magnets. This is one of the desirable features of the rotating type of magnet allowing the reduction to a minimum. Referring to Fig. 1 of the paper, it will be noted there are four magnets, and that each magnet can operate four or eight accelerating switches and results in a very reliable controller.

He next refers to a controller, that uses an induction regulator for giving a varying voltage. This is a comparatively new development, and it is hoped in the near future we may have a paper by those who are building this type of controller.

Since this brings up the question of smoothness or the elimination of the sensation of accelerating or retarding steps, it is desired to state that it has not been found difficult entirely to eliminate these sensations with the equipment covered in this paper.

A STROBOSCOPIC METHOD OF TESTING WATTHOUR METERS[1]

(Sparkes)

New York, N. Y., February 11, 1927

W. B. Kouwenhoven: The method described by Mr. Sparkes is very ingenious. The arrangement that he has provided, for changing the speed of his flashing lamp so as to bring it into synchronism with the marks on the meter disk, makes it possible to use the device to check over a wide range of speed.

The method should give accurate results, as the torque of the wattmeter measuring the a-c. load, is balanced by the torque of a d-c. voltmeter element supplied with current from a magneto driven from the flasher shaft. Care must be taken to see, that the armature reaction of the magneto is negligible, otherwise errors may be introduced.

I regret to note that the author has found it necessary to put 300 marks on the meter disk. This requires a high-speed lamp of special construction, and special apparatus in the laboratory always means trouble. If, however, he had used fewer marks and a standard lamp, which would operate at a low speed, he could not have obtained such a high degree of accuracy for his device.

I think that his statement, that his method is excellent for gang meter testing is open to question.

As I see it, the advantages of Mr. Sparkes' method, depend upon the fact, that it is easier to detect a departure from zero than it is to read a meter accurately. Mr. Sparkes' method, also does away with the necessity of calculation and meter reading, as the scale provided in his device reads per cent error directly. It should give good results in the hands of the unskilled meter tester.

B. J. Brown: I am very much interested in some points made by Dr. Kouwenhoven, particularly to anything that would give trouble in the future in the apparatus, especially such that develops after service.

1. A. I. E. E. Journal, April, 1927, p. 356.

In regard to the number of marks on the disk, can they be reduced? And the lamp, could it be changed?

And also its use in gang testing? There are other devices on the market. I would like to hear somebody's opinion regarding them.

H. J. Blakeslee: Mr. Sparkes has made a distinct advance that doubtless will eventually be of benefit, to meter manufacturers and electric light and power companies alike.

For many years efforts have been made to reduce the time required for testing watthour meters. Mr. Brown has just spoken of the group methods of testing. There are a number of such methods in use, and also a number of methods for making at least a part of the test automatic and so eliminating the personal error.

Group methods reduce the time required not only for determining the accuracy of the meters, but also for making the necessary records and for removing the covers, hanging the meters in position, connecting them in circuit and reversing those operations. It has been found that the actual time required for testing a meter is small in comparison with the total time required for the entire procedure.

However, every advance of this kind in reducing the time required for the test is an incentive to reduce the time for the balance of the operation, and for that reason I do not wish at all to disparage Mr. Sparkes' contribution. I think that efforts will follow to catch up on the other end of the process.

I do not understand just what Mr. Sparkes means by his statement that he is able to make tests to an accuracy of 0.0026 per cent. As I understand it, in the apparatus which Mr. Sparkes has described, the accuracy is dependent upon the precision of the per cent indicator and the accuracy to which it can be read. Possibly I am mistaken about that.

One of the most desirable features of Mr. Sparkes' method is the fact, that the meter is tested at speed so that any possible errors of start and stop do not enter into the result.

One other point which Mr. Sparkes has not brought out, but which should be borne in mind, is that his method is a distinct contribution to human welfare. Anyone who has intimate knowledge of the tediousness involved in counting meter revolutions day after day, will appreciate how relief from that monotony may add to the desirability of the meter tester's work.

G. A. Sawin: Referring to Mr. Sparkes' paper, the item that will most interest the operating man is his statement that this testing device will reduce personal errors and save time. Just how is this to be accomplished?

To illustrate, supposing we paint a picture of the meter man of the present and a possible meter man of the future. Today the meter man goes into the premises with a rotating standard and his load-box, connects up, and then counts the revolutions of the disk through his test meter. In order to avoid stopping and starting errors, and possible personal errors, he has to take a reading of three-quarters of a minute to a minute long and usually checks himself three times. I think that is the rule of most operating companies. He does the same thing at full load and at light load. Then if the meter is incorrect, he adjusts it a little bit and counts revolutions all over again, and he continues this same process until he gets the meter correct. Now the meter man of the future comes in. He has a box in his hand, which is probably about the same size as his present rotating standard, maybe smaller, and his load-box. He connects up, puts the testing device in front of the meter, adjusts the hand rheostat until the lines of the disk stand still, and reads his indicator. He has obtained his meter accuracy. He will probably check himself once, to make sure that he is right. He does the same thing at full load and at light load. You can see how much quicker that is, than the present method.

Now take your meter room where you have the laboratory device: in this case the flickering of the light is held constant by the standard meter. The tester knows that if the lines are

going one way the meter is fast; the opposite way it is slow. He puts a screw-driver into the full-load adjustment, turns that adjustment gradually; watches the lines slow down and finally stand still. The meter is calibrated. Of course, he will check himself to make sure he is correct, but there is no counting revolutions of the disk, no long waits, no stopping and starting errors.

As Mr. Sparkes says, the device is still in the experimental stage, but I think it marks a step forward. If we could only get away from that old bugbear of counting revolutions, it would be a blessing. I think Mr. Sparkes has earned a great deal of credit for showing us a possible way toward that end.

A. E. Knowlton: I should like to ask Mr. Sparkes to give an answer to this question: Does the logarithmic manipulation of the torque of the per cent indicator assure getting the same degree of accuracy of the percentage indication on a 50 per cent power-factor test as on a 100 per cent power-factor test?

The other question I would like to ask is: Does the limitation of the use of harmonic values of speed prevent accurate testing of the meter at 200 per cent or even 300 per cent of load, for which the claim is made, that a large number of meters now available are quite reliably accurate?

P. van Santen Kolff: Mr. Sparkes evidently needs in the tachometer a magneto that for a certain range of speed will give a perfectly straight curve. The particular magneto used by Mr. Sparkes has that characteristic. A much higher speed could be gotten, and still give a straight line curve, but, naturally slow speed tends to give more permanent and better commutation than high speed.

Mr. Sparkes might have added that the speed of his motor is by no means limited. If I understood his paper, all that Mr. Sparkes desires to do is to create a certain number of impulses, which may run to a maximum of maybe 8000 per min. for the flashing of his light; and by mounting more contact points or cams on his commutator, he naturally can reduce the maximum running speed of his motor and subsequently the speed of his magneto to any speed he likes. If a magneto at 600 rev. per min. would not serve his purpose, he could reduce that speed to 300 rev. per. min.

Mr. Sparkes wanted a lamp which would flicker very rapidly. Filling the lamp with hydrogen gas is ideal for accomplishing this. Nevertheless, if the bulb becomes cracked or for some reason oxygen and hydrogen become mixed in just the right proportion, a very dangerous explosion may result.

In Mr. Sparkes' work, danger from explosions must be absolutely eliminated. So his lamps, made up for him by our lamp laboratories, have very small bulbs, in fact, the bulb is about the size of an olive, and in these bulbs is less than atmospheric pressure of hydrogen gas. The danger of explosion is still there, but in Mr. Sparkes' apparatus he has the lamp enclosed in a fixture with a piece of plate-glass about ten times as thick as is needed, so the danger is so small as to be negligible. Furthermore, if his later experiments show it is necessary, we may fill these lamps with helium gas, which is almost as good for the lamp, and with it there is no danger from explosion.

H. P. Sparkes: Dr. Kouwenhoven's first question concerns the characteristics of the magneto. In developing this machine as far as it is developed, care was used in choosing the proper speed range. We selected from the curve of the magneto that portion which we may term "straight." The machine has been operated from 4 per cent load on the watthour meter to approximately 200 per cent. In the range of the magneto we are using that section of the curve which is straight for such operating conditions. The straight-line range runs from approximately zero to 1200 rev. per. min.

The next point brought out under Dr. Kouwenhoven's discussion was the question as to whether the number of lines could be reduced or not. All electrical men are familiar with the fact that after passing approximately 30 cycles, the vision of light interruption ceases; in other words, the eye is not sensitive enough to record over 30 cycles. Keep in mind that when operating this machine at light load, we must have a large number of lines passing the focal center of the eye within a given period, otherwise we cannot get the stroboscopic effect, we see the actual motion. It is therefore necessary to keep the stroboscopic lines on the disk in the vicinity of 300 or better. Experimental tests were made at 200, and at present we are working at 300. Some tests were made at 360, but care will have to be used in selecting the number of lines to match the watthour constant of the meters now being used. I make that remark because in calibrating with this device it will be necessary to supply a switch to take care of the various constant values as applied to various makes of meters.

I believe the point about the mechanism running at high speed is covered in the past remark concerning the lines.

For a reply to the question on special lamps see Mr. Beggs' remarks.

Another point which I wish to emphasize is the fact that the machine entirely eliminates personal error other than bad vision.

As to the point of gang testing, the term is applied in several different ways. You may make a gang test where the meters all stop and start at the same time. You start them all, time them, stop them, go over and adjust those that are out of calibration. With the stroboscopic machine you turn on the machine with the gang test running and in place of checking, you go along and calibrate while the load is on the meters. It eliminates the cut-and-try method.

As to Mr. Blakeslee's remarks, I would like to bring out one point in his statement. The meters, when placed on acceptance test, may be checked and passed, if they are within limits of required accuracy, without breaking the seals or removing the covers. The lines are placed on the circumferential edge and have a greater visibility than the present calibrating mark on the disk. This means that there will be considerable saving in time in the actual set-up for the test. That is, it will not be necessary to remove the metal covering, because the light beam can be projected through the glass opening on to the disk and a check made without touching the original manufacturers' seals.

The accuracy figures given in the paper, 0.0026, are based on calculations of the ultimate accuracy, and I believe in the paper I remark that the accuracy is based entirely upon the regulator, and as the regulator is composed of a precision wattmeter, you may see quickly that the accuracy of the entire machine or the overall accuracy depends entirely upon the linkage in the machine, 0.0026 being the ultimate accuracy according to visibility. Those figures are taken on what you may see through a 16-power cylindrical lens; in other words, that is the maximum.

Mr. Knowlton asks the question as to 50 per cent power factor. At 50 per cent power factor, we have the same change in the stroboscopic machine as you have in the watthour meter, so there will be no effect to introduce an error at this point, the stroboscope will follow the load with the meter and will act as though the meter had simply had the 50 per cent power-factor load placed on it, and the stroboscope will follow right through with it. I have made a number of tests at this point with the machine and no errors were found.

The last point brought out by Mr. Knowlton is an important one, concerning the harmonic adjustment. In developing this machine, I found that the eye is subject to a number of tricks. For instance, we are running the machine at twice the speed of the meter. The result is that the number of lines will apparently be double the actual number because you are taking a picture with your eye, of the line in two positions in place of one. Reverse the condition, with the meter running at 200 per cent and the stroboscope at 100, and you will be taking the opposite condition, every other line. In fact, you can check harmonic values from zero up to about 200 per cent. But realize what happens when you strike those harmonic values you are possibly working at one-half of 0.0026, which makes the point unstable so that it is

impossible to hold it; you have reduced your vision by the multiplier of your harmonic, and as a result your vision is exceedingly poor. At some harmonic values you have to reduce the light in the room or the external source of light to practically total darkness to observe some of the harmonic values. I have used colored glasses to determine some of these harmonic values.

Now, a point that hasn't been discussed is the question of using a lens multiplier at light load. Remember at light load you are getting an impulse-light. The light condition actually goes off and on to the human eye, meaning that the retina of the eye and the iris will get a flicker of light. Now the eye will automatically adjust itself to an intermediate position. You cannot follow the stroboscopic action at exceedingly light load by simply glancing at it. You have to give the eye several seconds, possibly, to see the extreme light-load conditions. By using a cylindrical lens in front of that moving object, it apparently speeds up the action to the eye and you get away from the eye delay.

In the criticism of the paper, the point was brought out: Does the stroboscopic machine have any effect upon the eye, such as injury to sight or fatigue to the eye? I would like to bring out one point here, and that is this: The optician today, with his methods of correcting eye trouble, often places an image on the edge of a wheel and asks you to watch that. The effect is that your eye rotates, exercising the muscles. In the case of the stroboscope operating at slow speed, you exercise the muscles in the eye. I have been operating this machine over a period of a year and I have had no eye trouble from it.

THEORY OF ACTION OF THE INDUCTION WATTHOUR METER AND ANALYSIS OF ITS TEMPERATURE ERRORS[1]

(Canfield)

New York, N. Y., February 11, 1927

W. H. Pratt: I think it should be emphasized that the present paper, except so far as it describes a particular mechanism for effecting compensations, is a restatement of material most effectively presented by Kinnard and Faus at the midwinter convention two years ago. Previous to that time, meters having much smaller Group II errors than those used for a background of this paper were used in predominant numbers, and since then the whole output of one of the largest producers of meters has been substantially without Group I errors. So that, presented at this time, the background of this paper must not be looked upon as a picture of general present-day practise.

The treatment of potential-circuit resistance, while perhaps not in error, tends, I think, to give a wrong impression and seems to be somewhat of an apology for high resistance in the potential circuit, whereas it was shown beyond peradventure in the Kinnard-Faus paper that resistance in the potential circuit is the outstanding source of Group II errors. Of course it is not possible to produce meters with zero resistance in the potential circuit, but this is not necessary. It is quite possible to make meters with a resistance so low that the use of manganin lag plates is convenient and the residual Group II errors are of almost vanishing value.

The results shown in Fig. 11 of the paper are excellent, but it appears that they are the results of painstaking individual adjustment. At present meters are in use which, however, even surpass this Fig. 11 performance, not as the result of adjustment but by reason of proper regard taken in the design of the various sources of error. They are inherently without errors exceeding 0.2 or 0.3 per cent, within the limits of application ordinarily prevalent. To be sure, they are portable test meters, though similar meters for switchboard use arranged for connection to 2-stage current transformers are also in service. Incidentally, manganin lag plates are used in these meters. It does not appear that the author advocates for general use the forms of compensation he describes. It seems that it would be necessary to use them with great caution, for there must be an ever present menace of maladjustment and disarrangement. Be that as it may, were I to venture a prediction in regard to future meter practise, I should say that in all probability in the not distant future, meters which have temperature characteristics not greatly inferior to the best performance here shown will be in general and extensive use.

As pointed out in the Kinnard-Faus paper, sources of error should be eliminated, and only when further elimination is impossible should recourse be had to compensation.

B. J. Brown: In regard to the paper by Mr. Canfield, how long have these compensating devices been in use? Time shows any small mechanical troubles, and often time only will develope them.

I. F. Kinnard: In my opinion, the most outstanding feature of the paper is the fact that the conclusions reached by Mr. Canfield agree substantially with the findings made by Mr. Faus and myself several years ago, in so far as classification of temperature errors into two distinct groups is concerned.

It is rather unfortunate that Mr. Canfield's analysis is entirely qualitative, since the listing of so many errors as he shows in Table I is likely to be misleading and does not give any sort of an idea as to just how important each error is from the standpoint of the meter's operation. In looking down this list, we see under Error 1, "Changes in the magnetic properties of the permanent magnet." As a matter of fact, this is by far the greatest source of Group I errors with which we have to contend. The other six errors listed under this group are of very little practical importance. We have determined this from exhaustive tests on a large number of meters, by means of which was made a quantitative study of the magnitude of the various errors involved. This error due to the changes in the magnetic properties of the permanent magnet with temperature, is something that is quite fundamental and cannot readily be eliminated. It therefore seems feasible to use some sort of a compensating device in order to keep the braking flux constant over wide variations in temperature.

Now in regard to Class II errors or those errors which cause a shifting in the phase relationship of fluxes with variations in temperature; Mr. Canfield has given an exhaustive list of possible sources of error of this nature. I have found, however, that there is only one really important source of error of this nature with which we have to contend. One which not only causes a shifting in phase relationship of fluxes with varying temperatures but which is reflected in various other factors of the meter's performance. I am speaking of the resistance of the potential windings. In an ideal meter, we should have all reactance and no resistance in the potential windings; that is, we want the flux to be in quadrature with the applied voltage. If it is not, we have to use some sort of a device to "lag" the useful portion of this flux through a small angle, with which all meter men are familiar. The only practical reason, therefore, for our having to put up with temperature errors of this nature is the existence of resistance in the potential windings.

I say this without hesitation, because meters are in actual service in which the potential coil resistance has been reduced to the point where the lagging can be accomplished by means of a manganin lag plate and the resulting errors are no longer of any commercial or practical importance whatsoever.

It is true that the compensation for both Class I and Class II errors, which the author has described in this paper, will work providing everything is in very nice adjustment, and he should be complimented on this solution. As someone has mentioned in a previous discussion, however, the real way to get rid of errors of any kind is to eliminate them at their source rather than use a compensation whereby it is endeavored to force two wrongs to make a right.

1. A. I. E. E. Journal, April, 1927, p. 328.

A. R. Rutter: The paper presented by Prof. Canfield is of great value, I think, not only in adding additional data to our literature on the watthour meter by discussing the temperature compensation, but by discussing the vector diagrams of the induction type watthour meter in dealing with the various vectors of eddy currents, of fluxes and of the current, and of voltage. The induction type watthour meter is usually regarded as a very mysterious piece of apparatus, so that a paper which presents a good analysis of the performance of the meter is a real addition to the literature on the subject.

Prof. Canfield refers to Fig. 6 of the paper and states that the results obtained in using a method of compensating for the Class II errors by lagging both the current and voltage fluxes gives a slight improvement for these errors. I think it is possible to interpret from his curves in Fig. 6 that if the compensation for Class I errors, (which are shown in his Fig. 8) were added to the compensation for Class II errors (as shown in Fig. 6), it should produce a very well compensated meter. I am familiar with results of this method, which produced meters which were carefully compensated for Class II errors by lagging both the current and voltage fluxes. This method has the advantage that compensation is obtained by changes in material and not by shifting mechanical parts.

C. T. Wallis: I have been working with alloys which change their magnetic properties with temperature, and observations over a period of about seven years have shown these to be very constant indeed.

With regard to the use of bi-metallic compensators which depend upon the expansion and contraction of two dissimilar metals these are rather erratic in their action. Considered strictly from a mass-production standpoint the air-gap between the magnet and the shunt which is carried on the bi-metallic strip must be adjusted very carefully at some definite temperature. On the other hand, the use of a permanently fixed magnetic shunt which changes its properties with temperature has none of the above disadvantages.

D. T. Canfield: In reply to Mr. Brown's question, I should like to say that the meters described in my paper have not been in commercial use at all. They have been used in my laboratory, however, for a matter of 2.5 or 3 years.

As Mr. Kinnard points out, I have no method other than a guess in my process of analysis of determining the relative magnitude of the several errors mentioned in Table I. I have no doubt whatever as to the overall error of the meter as a whole. That has been very definitely determined by me on all makes of meters a number of times, so that I do know, and did know at the time that this work was started, the amount of overal error that actually existed.

I claim that this resultant effect, in the last analysis, is the important feature. It is instructive and interesting only more in an academic way than in a practical way to analyze this overall error into its several component parts, and that is why I made no attempt to do it quantitatively.

As Mr. Pratt points out, the ideal way to eliminate error is to do away with the source of error, but as he also points out, it is not possible to eliminate the errors completely in this way. No claim is made in my paper that the method of compensation used by me is the only one. In fact, my Fig. 5 shows that the method proposed by Mr. Pratt is effective in reducing Group II errors.

Mr. Rutter's remarks concerning Fig. 6 and the method of compensation therein illustrated are well founded. The particular meter used in this experiment was of an obsolete variety which had the desired compensation as far as Group II errors were concerned but was decidedly off on Group I errors. As far as this figure is concerned the compensation of Group I errors would not materially affect the slope of the curves.

This does not detract, however, from the merits and advantages of this method of compensation. It is necessary only to obtain the proper proportion of the counteracting lagging devices to give theoretically perfect performance.

As Mr. Wallis points out, it is necessary to carefully form and age the bi-metal strips used on the compensating devices. When this is done, I have found no indication of subsequent change.

ILLUMINATION ITEMS

By Committee on Production and Application of Light

BRITISH INVESTIGATE LIGHT AND INDUSTRIAL EFFICIENCY

Great Britain has made a most valuable contribution to the data relative to the value of good lighting in industry through an investigation (reported jointly by the Industrial Fatigue Research Board and the Illumination Research Committee) on The Relation Between Illumination and Efficiency in Fine Work (Type setting by hand)* The report is issued by the Medical Research Council and Department of Scientific and Industrial Research.

The prefatory note appearing over the name of the latter department reads as follows:

During recent years the subject of industrial lighting has received much attention in this country. The Departmental Committee on Factory Lighting, appointed by the home office in 1913, have issued three reports on the subject, the first dealing with the *general* lighting of factory premises in regard to adequacy of illumination; the second, with the suitability of lighting installations in regard to glare, shadow, etc., and the third, with the illumination required on the working plane for different processes.

In the last of these reports, schedules of "fine" and "very fine" processes are given with tentative suggestions as to the minimum illuminations required, but at the same time, the need for more precise knowledge of the conditions of illumination desirable on physiological and psychological grounds is strongly emphasized.

Shortly after it was appointed by the Department of Scientific and Industrial Research to study illumination on general lines the Illumination Research Committee was informed that the home office had submitted several problems which it was suggested should be investigated. Among these was the relation of illumination to the efficiency of workers engaged on fine processes.

After full consideration, the committee decided to select hand-composing in letterpress printing as the first example of fine work to be studied, and in view of the methods of investigation to be adopted, it invited the collaboration of the Industrial Fatigue Research Board of the Medical Research Council, who seconded Mr. H. C. Weston to undertake the work with the assistance of Mr. A. K. Taylor of the National Physical Laboratory. Further, in order to insure adequate

*Copies can be purchased directly from H. M. Stationery Office, Adastral House, Kingsway, London W. C. 2. Price 6d. net.

technical criticism, the Joint Industrial Council for the Printing and Allied Trades were approached and agreed to nominate Mr. A. E. Goodwin and Mr. A. E. Holmes to join a special subcommittee appointed to supervise the investigation.

The results, which will be of interest not only to industrialists but also to illuminating engineers, are now published as a joint report of the Industrial Fatigue Research Board and Illumination Research Committee.

The main conclusion to be drawn from the investigation (which although based on the observation of only two subjects has yielded data very consistent amongst themselves) is that output does not reach its maximum daylight value (and errors and turned letters their minimum value) until an artificial illumination of the order of 20 foot-candles is attained, which, so far as can be ascertained, is a very much higher illumination than that usually found in printing offices at present.

An increase of illumination perse appears, however, to be open to the risk of discomfort to the compositor arising from glare or heat from the source, and the most suitable method of attaining this illumination without such inconvenience is now under investigation.

The special thanks of the Board and the Committee are due to Messrs. Kelly's Directories, Ltd., for permitting the experiment to be carried out at their printing works.

The report then gives very complete data on the tests conducted. Variations in output, errors and turned letters were studied with daylight illumination and with a range of artificial illumination from 1.3 to 24.5 foot-candles. The effects of Adaption and Fatigue are discussed. The net conclusion is that an optimum value of illumination for hand composing exists and that it is about 20 foot-candles. With illumination less than two foot-candles the possible output is reduced nearly 25 per cent (and mistakes are more than double) while at seven foot-candles the output is still 10 per cent below its possible value.

In the United States, lighting code typesetting comes in the group of operations for which "10 to 20 foot-candles and above" is specified. It is most interesting to see that a test carefully conducted in another country not only confirmed this classification but justifies the selection of relatively high value within the range specified.

CARBON LAMPS

The Lamp Committee of the National Electric Light Association published during March 1927, a report emphasizing the fact that more than eighteen and a half million large carbon lamps were sold in this country last year, and that where these lamps are used, electrical energy is converted into light under a handicap of a degree of inefficiency which is detrimental to the public interest and to the lighting service.

Only a relatively small number of these lamps (about 10 per cent) has been used where mechanical shocks or vibration precluded the satisfactory use of the old types of tungsten filament lamps and recent improvements and developments have now permitted even this last stronghold of the carbon lamp to be invaded by the much more efficient types.

It appears that about sixteen million of the eighteen and a half million carbon lamps are used for general lighting service where strength has not been the prime consideration. These lamps are selected, it is believed, because of their low first cost, their unusual shapes, or for their decorative effects, a large proportion of them being colored. They are not infrequently purchased under the impression that they are tungsten filament lamps of low wattage, whereas instead of consuming perhaps 25 watts, they may consume considerably more. The low price of these inefficient lamps appeals to many who can ill afford to pay the high price for light which their use entails.

To the end that electric service should not be discredited through the dissatisfaction which is bound to result from the use of inefficient lamps, no matter how cheap they may be in first cost, the report recommends that every reasonable assistance be given to customers to make the most intelligent use of electricity.

With regard to the use of carbon lamps where mechanical strength is important, the report refers to the recent development of a "rough service" tungsten filament lamp which preserves much of the efficiency of the regular tungsten filament lamp (it is about 85 per cent as efficient) while serving satisfactorily under the severe conditions in which heretofore only carbon lamps could give satisfaction. Results of tests on the relative ability of the two types of lamps to withstand bumps are given. The choice of lamp guards for use on extension cords is discussed briefly. The heavy guards which can protect the lamp from heavy objects falling on them, are so rigid that the impact on dropping is more severe than when a lighter construction is used.

The use of lamps under conditions of vibration, (such as when they are mounted on or near high-speed machinery), is also discussed, this condition requiring different treatment than that where the lamp is subjected to mechanical shocks and rough handling. In such conditions vibration absorbing devices may be used; or the lighting may be re-arranged to replace several small lamps with one large one, the larger lamps being better able to resist the effects of vibration; or the use of general overhead lighting will often make the use of local lighting unnecessary. The 50-watt tungsten filament lamp which is made in the P-19 bulb is more efficient than the rough service lamp, and is more satisfactory than either the rough service lamp or the standard construction in the A-bulb commonly known as the inside frosted line, where vibration is encountered.

The report concludes with a summary of recommendations based on the study of the subject.

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The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

The Bethlehem Regional Meeting

An enthusiastic and well-attended regional meeting of the middle eastern district of the A. I. E. E. was held at Bethlehem, Pa., April 21-23, 1927. The technical sessions developed much animated discussion, the dinner dance called out the full attendance at the meeting—about 400 members and guests—and the lecture by Dr. Berg was replete with interesting reminiscences of Heaviside and Steinmetz. As the meeting closed just as the Journal went to press only a brief account is possible.

Thursday Morning

The first technical session was called to order by Vice-President A. G. Pierce who welcomed the delegates in a short address after which he introduced Mr. William E. Lloyd, Jr., Chairman of the of the Committee in Charge of the Meeting who gave some brief remarks and announcements. Prof. William Esty, of Lehigh University was then invited to occupy the chair.

Two papers were presented; the first by R. M. Spurck on *Oil Circuit Breaker Development*; the second by J. B. Moorehouse on *Reducing Losses in Electric Systems.* Both papers provoked vigorous discussion.

Thursday Afternoon

The session Thursday afternoon was held in the Physics Building of Lehigh University and was called to order by Mr. Pierce who introduced Dr. C. R. Richards, president of Lehigh University. Dr. Richards gave a brief address of welcome during which he recounted the founding and growth of the University and explained some features of the engineering curricula. Prof. F. C. Caldwell, of Ohio State University, acted as chairman.

Three papers were presented as follows: *Improvements in Large Induction Motors*, by D. F. Alexander; *Intercommunication in Industrial Plants*, by L. A. Cutshall; *The Mercury Arc Rectifier*, by O. K. Marti and Harold Winograd, read by the former.

The Dinner Dance

A most enjoyable gathering of about 400 members and guests, a large portion cf whom were ladies, occurred at the dinner dance on Thursday evening, April 21, in the Banquet Hall of the Hotel Bethlehem. Addresses by distinguished speakers, musical entertainment and dancing, added to the pleasure of this affair. D. M. Petty, Electrical Superintendent, Bethlehem Steel Company, was toastmaster. Short addresses were made by James M. Yeakle, Mayor of Bethlehem, and Dr. C. R. Richards, President of Lehigh University, A. K. Baylor of the Executive Staff of the General Electric Company, then spoke on the subject of "Search and Research." The principal speaker was Frank A. Arnold, Director of Development of the National Broadcasting Company. He told of the tremendous growth of the radio industry and gave an interesting insight into many of the phases of broadcasting.

Friday Morning

This session was held at the Hotel Bethlehem and was opened by Mr. Pierce who invited Mr. H. W. Lesser, of Frackville, Pa., to preside. Mr. Lesser called upon W. E. North to present his paper *Application of Electricity in Cement Mills.* This was followed by the presentation of a paper entitled *Application of Electric Power to Anthracite Mining*, by E. B. Wagner.

Friday Afternoon

The final technical session was held on Friday afternoon and was called to order by Mr. Pierce who invited Mr. William E. Lloyd, Jr., to preside. Three papers were presented as follows: *Recent Developments in Electric Drive for Rolling Mills*, by L. A. Umansky; *Lightning and Its Effect on Transmission Lines*, by J. H. Cox; Committee Report on *Voltage Standardization*, by B. G. Jamieson. This marked the close of the technical sessions.

Dr. Berg Speaks on Heaviside and Steinmetz

Dr. Ernst J. Berg, of Union College, gave an inimitable account on Friday evening at Lehigh University of his personal reminiscences of Oliver Heaviside and Dr. C. P. Steinmetz. Dr. Berg knew these two great men as perhaps no one else did, and his initimate stories held his audience in closest attention.

Conference on Student Activities

A conference of Student Branch representatives and others interested was held under the auspices of the Committee on Student Activities of District No. 2 on Saturday morning, April 23, at Lehigh University. Nearly all of the eighteen Branches in the District were represented by their Counselors and Chairmen. Prof. H. B. Dates, of Cleveland, presided.

An account of the discussion may be found in the Student Activities Section of this issue of the Journal.

Inspection Trips

An unusually large proportion of those at the meeting made one or more of the interesting inspection trips, most of which were arranged for Saturday morning. The most popular trip, that to the Bethlehem Steel Company, drew an attendance of almost a hundred. The trips to the Siegfried Substation of the Pennsylvania Power & Light Company, and to the Lehigh Portland Cement Company, also were well attended. Many of the visiting ladies enjoyed sightseeing tours.

The general committee, to the excellent work of which the success of the meeting was due, consisted of Messrs. William E. Lloyd, Jr., Chairman, C. S. Ripley, Secretary, R. T. Greer W. H. Lesser. A. G. Pierce, D. M. Simons, M. R. Woodward D. M. Petty, J. L. Beaver, L. C. Josephs, H. G. Harvey, J Huebner, L. R. Woodhull, and George M. Keenan.

Pittsfield Regional Meeting May 25-28, 1927

A charming location, enjoyable recreation, technical papers of unusual interest and the artificial production of a most spectacular electrical phenomenon are the outstanding features planned for the 4th Annual Meeting of the Northeastern District to be held at the Maplewood Hotel, Pittsfield, Mass., on May 25-28.

A Most Attractive Location

No finer place than Pittsfield, in the heart of the Berkshires could have been selected for this meeting. In addition to the lure of an interesting romantic history and tradition, the Berkshires have a scenic loveliness that is particularly their own. Their charm lies not in imposing grandeur but in their varying beauty—range after range of rolling wooded hills, rushing mountain streams, lakes and ponds and beautiful fertile valleys. All these and more may be enjoyed by driving over the many scenic highways in this region. The Maplewood Hotel in its beautiful setting, with its ample parlors and verandas, has been reserved exclusively for this meeting.

Nor are these the only inducements. Here is the home of the Institute's President. Here the transformer was born and developed and now is being built in the largest transformer factory in the world. Here is the birthplace of artificial lightning. Here is made the paper for the money of this country, as well as the finest writing paper and paper for other purposes, and here also are textile mills of various kinds.

Last, but not least, is the spacious Country Club with its beautiful golf course nestling at the foot of the hills.

Technical Sessions

Six groups of papers will be presented in as many sessions. The first, a symposium on high-frequency measurements will probably require an entire session for presentation and a short session, in parallel with one of the other sessions, for discussion. Among the other groups will be found such subjects as transformer tap-changing under load, mechanical forces in electrical apparatus and others of equal interest. Special consideration will be given to "First Papers" and to the Friday afternoon session, reserved for papers by Student Branch members. More complete information is given in the accompanying program.

Meetings of the Branch Counselors and of the District Executive Committee will be held during the convention.

Inspection Trips

The outstanding inspection trip will be to the Pittsfield plant of the General Electric Company. Here are built transformers of various sizes, current-limiting reactors, lightning arresters, capacitors, feeder voltage regulators and certain lines of small motors. This is also the location of the high-voltage laboratory in which visitors will be given the opportunity to witness artificial lightning demonstrations as well as the million-volt three-phase arc. Other inspection trips, for those who so desire, are arranged to various paper and textile industries in the immediate vicinity.

Entertainment

On Wednesday evening there will be an informal reception and dance, with cards for those who desire. On Thursday evening an informal banquet for delegates, members, and their ladies will be given, followed by an entertainment in the hotel dining room. On Friday night Professor Vladimir Karapetoff will give one of his delightful musical recitals and there will be a lecture of general interest.

A ladies' committee has been appointed to provide entertainment for the visiting ladies during technical sessions. At other times the ladies are invited to joint the delegates.

The sports committee will arrange for golf, tennis, etc.

Registration

A registration and information bureau will be provided in the hotel lobby. Delegates. however, are requested to register in advance as far as possible, sending their registration to Mr. C. H. Kline, General Electric Co., Pittsfield, Mass.

In order to cover part of the necessary expenses for lecture hall, etc., a small registration fee of $1.00 will be made for the men.

Hotel Accommodations

Convention headquarters will be at the Maplewood Hotel where 250 guests can be accommodated. Requests for reservations should be sent directly to the Maplewood Hotel. Rates per person including meals are as follows: Double room without bath, $7; with connecting bath, $8; single room without bath, $7; with bath, $9.

In case the requirements for accommodations exceed the capacity of this hotel, the management will make suitable reservations in one of the nearby hotels in Pittsfield and so notify those who cannot be accommodated at the Maplewood.

Regional Meeting Headquarters, Pittsfield, Mass.

If delegates so accommodated at other hotels desire, the Maplewood will extend to them its dining-room service at a total cost for accommodations and meals as given in the above rates.

PROGRAM

(All technical sessions will be held in the Maplewood Hotel)

Wednesday Morning, May 25

9:00 a. m. Registration

10:00 a. m. Address of Welcome, by H. M. Hobart, Vice-President, District No. 1, A. I. E. E.

10:30 a. m.

Technical Session—Symposium on High-Frequency Measurements, A. E. Knowlton, Chairman.

Notes on the Use of a Radio-Frequency Voltmeter, W. N. Goodwin, Weston Electrical Instrument Corp.

Substitution Method for the Determination of Resistance of Inductors and Capacitors at Radio Frequencies, C. T. Burke, General Radio Co.

Condenser Shunt for Measurement of High-Frequency Currents of Large Magnitude, A. Nyman, Dubilier Condenser & Radio Corp.

Radio-Frequency Current Transformers, Paul MacGahan, Westinghouse Electric & Mfg. Co.

Methods for Measurement of Radio Field Strengths, C. R. Englund and H. T. Friis, Bell Telephone Laboratories, Inc.

Quantitative Determination of Radio Receiver Performance, H. D. Oakley, General Electric Co.

High-Frequency Measurements of Communication Lines, H. A. Affel and J. T. O'Leary, American Telephone & Telegraph Co.

Measuring Insulation of Telephone Lines at High Frequencies, E. I. Green, American Telephone & Telegraph Co.

High-Frequency Measurements of Communication Apparatus, W. J. Shackelton and J. G. Ferguson, Bell Telephone Laboratories, Inc.

Impedance of a Non-Linear Circuit Element, Eugene Peterson, Bell Telephone Laboratories, Inc.

Empirical Analysis of Complex Electric Waves, J. W. Horton, Bell Telephone Laboratories, Inc.

A New Thermionic Voltmeter, S. C. Hoare, General Electric Co.

The Oscilloscope, a Stabilized Cathode-Ray Oscillograph with Linear Time Axis, Frederick Bedell and H. J. Reich, Cornell University.

Sensitivity Characteristics of a Low-Frequency Bridge Network, P. G. Edwards and H. W. Herrington, American Telephone & Telegraph Co.

Microammeter Indication of High-Frequency Bridge Balance, H. M. Turner, Yale University.

WEDNESDAY AFTERNOON, 2:00 P. M.

(A) Symposium on High-Frequency Measurements, continued.

(B) Technical Session—Mechanical Forces in Electrical Circuits.

F. L. HUNT, CHAIRMAN

Mechanical Forces between Electric Currents and Saturated Magnetic Fields, V. Karapetoff, Cornell University.

The Calculation of Mechanical Forces in Electric Circuits, H. B. Dwight, Massachusetts Institute of Technology.

Experimental Measurement of Mechanical Forces in Electric Circuits, J. Walter Roper, Massachusstts Institute of Technology.

Mechanical Forces in Transformers, J. E. Clem, General Electric Co.

WEDNESDAY EVENING, 8:30 P. M.

Informal Reception
Dancing and Cards

THURSDAY MORNING, 9:00 A. M.

TECHNICAL SESSION—TAP CHANGING ON TRANSFORMERS

W. S. MOODY, CHAIRMAN

Changing Taps on Transformers Under Load, L. H. Hill, Westinghouse Electric & Mfg. Co.

Characteristics of Interconnected Power Systems as Affected by Transformer Ratio Control, L. F. Blume, General Electric Co.

Load-Ratio Control Equipment, Arthur Palme, General Electric Co.

THURSDAY AFTERNOON, 2:00 P. M.

Inspection of Pittsfield Plant of General Electric Co.
Artificial Lightning and 1,000,000-volt three-phase arc
Golf and Tennis

THURSDAY EVENING, 6:30 P. M.

Convention Dinner and Entertainment

FRIDAY MORNING, 9:00 A. M.

TECHNICAL SESSION

H. B. SMITH, CHAIRMAN

Sparking in Air, Adam Pen-Tung Sah, Worcester Polytechnic Institute.

A Theory of Imperfect Solid Dielectrics, Michel G. Malti, Cornell University.

High-Voltage Measurements on Cables and Insulators, C. L. Kasson, Edison Electric Illuminating Co. of Boston.

Non-Harmonic Alternating Currents, Frederick Bedell, Cornell University.

FRIDAY AFTERNOON, 2:00 P. M.
STUDENT TECHNICAL SESSION
W. H. TIMBIE, CHAIRMAN

Inspection Trips to Paper and Textile Mills

FRIDAY EVENING, 8:00 P. M.

Piano Recital, by Vladimir Karapetoff, Cornell University.
Convention Lecture.

SATURDAY MORNING, 9:00 A. M.

TECHNICAL SESSION

F. W. PEEK, JR., CHAIRMAN

Development of Automatic Switching Equipments in the United States & Europe, A. H. deGoede, General Electric Co.

Economical Power-Factor Correction, H. S. Litchfield.

Instability in Transformer Banks, K. E. Gould, Massachusetts Institute of Technology.

An Instrument for Measuring Short-Circuit Torque, E. W. Penney, Westinghouse Electric & Mfg. Co.

Reduction of Transformer Exciting Current to Sine-Wave Basis, G. Camilli, General Electric Co.

COMMITTEES

The General Committee in charge of the meeting is as follows: H. M. Hobart, Chairman, Vice-President Northeastern District, A. I. E. E.; A. C. Stevens, Secretary; E. C. Dickinson, A. E. Soderholm, W. H. Colburn, W. H. Timbie, C. F. Scott, C. W. Henderson E. F. Gehrkens and C. H. Kline.

The chairmen of the other committees are: Executive Committees, E. F. Gehrkens; Hotels and Registration, C. H. Kline; Entertainment, L. R. Brown; Ladies Entertainment, Mrs. R. W. McCracken; Sports, V. E. Goodwin; Inspection Trips, D. R. Dalzell, and Local Transportation, W. H. Cooney, 2nd.

Future Section Meetings

Akron

Inspection tour to the Avon Station of the Cleveland Electric Illuminating Company. In the evening, the Annual Meeting and a banquet will be held. May 14.

Cleveland

Annual Meeting. Speaker: C. C. Chesney, National President, A. I. E. E., May 19.

Columbus

Annual Meeting. Prominent speaker and election of officers. May 27.

Pittsburgh

Development of Executive and Administrative Ability, by F. J. Chesterman, Vice-President and General Manager, Bell Telephone Co. of Pa. Chamber of Commerce Building. 8:00 p. m., May 10.

St. Louis

Reyrolle Armor-Clad Switch Gear, by H. V. Nye, Allis Chalmers Co. May 18.

Sharon

Central Station Practise. June 7.

Vancouver

Annual Dinner Meeting. Election of Officers. June 7.

Photo by Detroit News

Skyline of Detroit's Business Section

Summer Convention at Detroit Will Have Fine Program

A remarkably well balanced list of papers, and a full program of attractive recreational features, will mark the coming Summer Convention of the Institute which will be held in Detroit in the Book-Cadillac Hotel, June 20-24. For the technical sessions, a large number of papers on practical operating subjects been chosen, in addition to some of the latest scientific and theoretical contributions. These papers include such subjects as power stations, transmission-line operation, relays, control circuits, cable joints, communication, dielectrics, corona, rectifiers, electrical units and electric traction. Practically all fields of electrical engineering will be covered in the reports of the Technical Committees, which are scheduled for presentation on Wednesday morning, June 22.

Engineers connected with railway companies will be particularly interested in the session on catenary suspension, at which five excellent papers will be presented on Friday, June 24.

Another technical feature of unusual interest will be the lecture by Professor C. T. Compton of Princeton University on the subject of "The Nature of the Electric Arc." This lecture will explain the phenomena of electric arcs in accordance with modern physical theories.

A full schedule of the events of the meeting is given in the tentative program which accompanies this announcement.

Attractions of Detroit

Both as an industrial city and a vacation center, Detroit offers many attractions. It is the fourth city of the country in population and its industry includes manufacturing, power generation, shipping, etc. In addition to being the world's largest automobile manufacturing center, it has hundreds of plants devoted to other industries. One of the world's most modern electrically-operated railroads, owned by the Ford Motor Company, centers there. Its power stations are among the greatest in the world. Trenton Channel Station of the Detroit Edison Company, a pulverized fuel plant which will have five 50,000-kw. turbo generators in operation, and the Connors Creek Station, are well known to electrical engineers.

Visits will be made to these power plants and other stations and to the automobile plants, steel mills, brass foundries, airplane factories, and other interesting places.

Detroit's central location makes it easy to reach from many sections by rail, boat, and automobile. Special railroad rates will apply.

Entertainment

The entertainment section of the program takes full advantage of the city's unusual location, situated as it is between Lake Huron and Lake Erie, with beautiful Lake St. Clair at its doorway. A moonlight excursion up the river and into Lake Huron will be one feature of the convention. There will be dancing on this trip, as well as on other nights.

The city of Windsor, Canada, is located just across the river from Detroit. One of the loveliest of the nation's municipal parks, Belle Isle, may easily be reached. This historic spot, which was a military prison during Civil War days, is now a play ground, with bathing beaches, beautiful canals, forests, horticultural gardens, conservatories, zoological gardens, and other attractions.

There will be golf and tennis tournaments at excellent clubs, and these will be among the attractions which it is expected will draw many to the meeting. Every afternoon of the convention will be open for sports and other recreational features.

There will be a complete program of entertainment, specially for the ladies, including sightseeing drives, teas and sports. The ladies will also attend the inspection trips, reception, dances, dinner, boat ride, etc.

Section and Branch Delegates Conference

Conference of delegates of the Institute Sections and of Branch Counselors will be held under the auspices of the Sections and Branch Committees on Monday, June 20. This entire day will

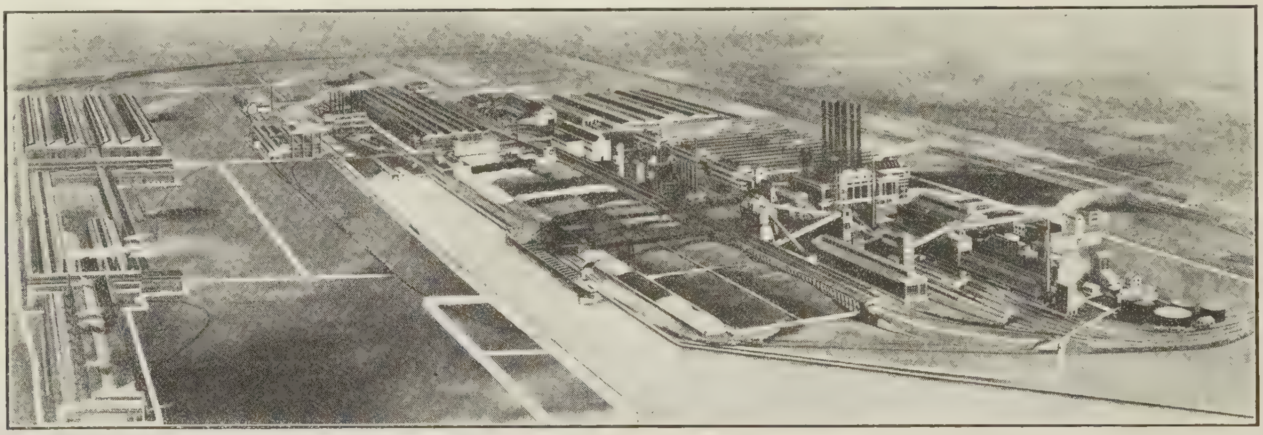
be devoted to a discussion of Section and Student Branch problems—the first technical session starting on Tuesday.

Hotel Reservations

The Hotel Committee in Detroit plans to make such arrangements that those who make hotel reservations will not be disappointed on arriving at the Book-Cadillac Hotel.

Lake Trip After Convention

Another event planned in connection with this convention is a three-day steamer trip from Detroit to Mackinac Island and



Ford Motor Plant Which Turns Out 10,000 Cars a Day

Georgian Bay. This trip will start on Saturday, June 25, the day following the close of the convention. More information on the trip is published elsewhere in this issue of the Journal.

Committees

A very active and enthusiastic group of committees is formulating plans for the convention. The personnel of the general committee is as follows:

General Convention Committee

Alex Dow, Chairman, G. B. McCabe, Vice-Chairman,

Entertainment:
G. H. Roosevelt, Chairman
L. Braisted, Vice-Chairman

Publicity:
A. MacLachlan, Chairman
Harold Cole, Vice-Chairman

Finance:
A. C. Marshall, Chairman
A. A. Meyer, Vice-Chairman

Registration:
F. H. Riddle, Chairman
T. N. Lacy, Vice-Chairman

Hotel:
J. W. Bishop, Chairman
F. R. Jennings, Vice-Chairman

Transportation:
C. Kittredge, Chairman
C. G. Winslow, Vice-Chairman

Local Trips:
E. L. Bailey, Chairman
F. L. Snyder, Vice-Chairman

Sections:
H. B. Smith

Meetings and Papers:
E. B. Meyer, Chairman
A. H. Lovell, Vice-Chairman

Student Branches:
C. E. Magnusson

Out-of-Detroit Members:
J. H. Foote B. G. Jamieson G. E. Lewis

TENTATIVE PROGRAM FOR SUMMER CONVENTION AT DETROIT, JUNE 20-24

Monday, June 20

9:00 a. m. Registration
10:00 a. m. and 2:00 p. m. Section and Branch Delegates Conference
8:30 p. m. Informal Dancing

Tuesday, June 21

9:00 a. m. Registration
10:00 a. m. Mayor's Address
President's Address
10:30 a. m. Technical Session
Holtwood Steam Plant, Design and Operation in Coordination with Water Power, F. A. Allner, Penn. Water and Power Co.
Auxiliary Power Supply for Richmond Station, J. W. Anderson, Philadelphia Electric Co., and A. C. Monteith, Westinghouse Electric & Mfg. Co.
Recent Investigations of Transmission-Line Operation, J. G. Hemstreet, Consumers Power Co.
Ground-Relay Protection for Transmission Systems, B. M. Jones and G. B. Dodds, Duquesne Light Co.
Use of High-Frequency Currents for Control, C. A. Boddie, Westinghouse Electric & Mfg. Co.

Book Cadillac Hotel, Detroit Convention Headquarters

2:00 p. m. Golf and Tennis Tournaments
Inspection Trips
8:00 p. m. Lecture—"The Physical Nature of the Electric Arc," by Dr. C. T. Compton, Princeton University
8:45 p. m. President's Reception and Dance

WEDNESDAY, JUNE 22

9:30 a. m. Presentation of Technical Committee Reports (These reports will be presented in two simultaneous sessions)
1:30 p. m. Trip to Trenton Channel Power Station
2:00 p. m. Golf and Tennis Tournaments
Trips
6:45 p. m. Dinner with Addresses by Prominent Industrial Leaders

THURSDAY, JUNE 23

10:00 a. m. Technical Session
Printing Telegraphs on Ocean Cables, Herbert Angel, Western Union Telegraph Co.
Electrical Reproduction of Sound, E. W. Kellogg, General Electric Co.
Electromagnetic Waves Guided by Parallel Wires, S. A. Levin, National Electric Light Association

TRENTON CHANNEL STATION OF DETROIT EDISON COMPANY

High-Voltage Multiple-Conductor Joints, Thomas F. Peterson, Brooklyn Edison Co.
The International Electrical Units, E. C. Crittenden, Bureau of Standards
2:00 p. m. Golf and Tennis Tournaments
Inspection Trips
7:30 p. m. Boat Ride and Dance

FRIDAY, JUNE 24

10:00 a. m. Two Technical Sessions A and B

SESSION A

An Investigation of Corona Loss, E. C. Starr and W. L. Lloyd, General Electric Co.
Law of Corona and Dielectric Strength, F. W. Peek, General Electric Co.
Puncture Voltage as a Precision Measurement, V. Bush and P. H. Moon, Massachusetts Institute of Technology
The Electrical Resistivity of Insulating Materials, H. L. Curtis, Bureau of Standards
Electric Strength of Solid and Liquid Dielectrics, Wm. A. Del Mar, Habirshaw Cable and Wire Corp., W. F. Davison, Brooklyn Edison Co., R. H. Marvin, Johns Hopkins University
Mercury Arc Rectifier Phenomena, D. C. Prince, General Electric Co.

SESSION B

Current Collection from an Overhead Contact System Applied to Railroad Operation, S. M. Viele, Pennsylvania Railroad
Catenary Design for Overhead Contact Systems, H. F. Brown, New York, New Haven and Hartford Railroad
Catenary Construction for Chicago Terminal Electrification of Illinois Central Railroad, J. S. Thorp, Illinois Central Railroad Co.
Collection of Current from Overhead Contact Wires, R. E. Wade and J. J. Linebaugh, General Electric Co.
Railway Inclined-Catenary Standardized Design, O. M. Jorstad, Westinghouse Electric & Mfg. Co.
2:00 p. m. Golf Tournament
Boating at Edison Boat Club

Lake Trip to Follow Summer Convention

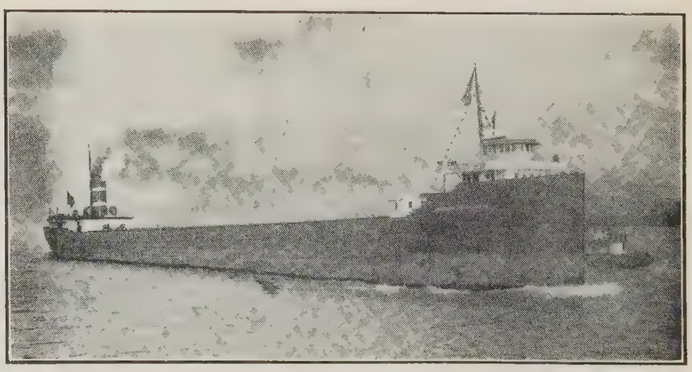
A steamer trip from Detroit to Mackinac Island and Georgian Bay is being planned for Institute members and their guests, to start on the day after the coming Summer Convention. This will be a three-day trip, starting from Detroit, Saturday, June 25, and returning to Detroit, Tuesday, June 28.

All members who are interested in this trip are requested to write to Institute headquarters, New York, in order to help the committee in making its plans.

The trip will be made on two of the larger steamers traveling the Great Lakes. From Detroit to Mackinac, a steamer of the Detroit and Cleveland Navigation Company will be used. From Mackinac through Georgian Bay and back to Detroit the trip will be made on a steamer of the Chicago, Duluth and Georgian Bay Transit Company. The following is the schedule of this trip:

Lv.	Detroit	Sat.	1:30 p. m. D. & C.
Ar.	Mackinac	Sun.	8:15 a. m.
Lv.	Mackinac	Sun.	4:30 p. m. C. D. & G. B.
Ar.	Parry Sound	Mon.	10:00 a. m.
Lv.	Parry Sound	Mon.	11:30 a. m.
Ar.	Detroit	Tues.	9:30 a. m.

The costs of this round trip will be $42.50 and $45.50, including meals and berth. Two passengers must share each stateroom. The lower rate includes transportation on Deck C of the C. D.



TWO OF THE THOUSANDS OF GREAT SHIPS THAT PLY THE WATERS OF THE GREAT LAKES AND PASS DETRIOT'S DOORS AND TOUCH AT ITS SHORES

and G. B. Steamer, while the higher rate includes transportation on Deck D-E.

Those who desire may continue on a steamer from Detroit to Cleveland or Buffalo; also, it will be possible to go from Detroit through Mackinac to Chicago, omitting the return trip from Mackinac through Georgian Bay to Detroit.

If a sufficient number show interest, this trip will be made practically as outlined above. More complete information will be sent to those who contemplate taking the trip.

A. I. E. E. Annual Business Meeting New York, May 20, 1927

DR. IVES TO TALK ON "TELEVISION"

The Annual Business Meeting of the A. I. E. E. will be held on Friday, May 20, 1927, at 8:15 p. m. (daylight saving time) in the Engineering Auditorium, 33 West 39th Street, New York, New York. At this meeting the reports of the Committee of Tellers on the annual election of Institute officers will be presented, as well as the report of the Board of Directors for the year ending April 30, 1927.

Following the business meeting, the New York Section of the Institute has arranged for a talk on "Television" by Dr. Emerson Ives of the Bell Telephone Laboratories. Dr. Ives will describe the development and operation of the apparatus used in television demonstrations recently given before representatives of industry and the press, during which Herbert Hoover talked from Washington with officials of the A. T. & T. Co. and the Laboratories, and at the same time was visible to them. Important parts of the apparatus will be on exhibit during the meeting. Arrangements will also be made so that it will be possible for all those in the audience who so wish, to visit the Bell Laboratories at stated times within the next few days following the meeting, to see an actual working demonstration of "television." It is probable tickets will be distributed at the meeting for this purpose. Because of the great interest shown in the subject, we suggest members come early.

American Society of Civil Engineers to Meet at Denver

The fifty-seventh Annual Convention of the American Society of Civil Engineers will be held at Denver, Colo., July 13 to 16. Able addresses, well-planned technical sessions, pleasure trips, and social events make prospects for a most successful and enjoyable time appear replete. The trip to the convention, in itself, will include a comprehensive tour of the Rocky Mountain region, and its good fellowship and high standards will no doubt make it possible to realize the fondest ambitions of all attending. Further details may be obtained from the headquarters of the Society, 33 West 39th Street, New York, N. Y.

Main Features of the A. S. M. E. Spring Meeting

In weighing the manifold attractions of White Sulphur Springs, which is the location that has been chosen by The American Society of Mechanical Engineers for its Spring Meeting, the Society is anxious that the technical excellence of the program shall not be overlooked. The number of authorities scheduled to speak upon important subjects is worthy of more than passing attention. Something of the scope of the meeting is indicated by the following list of subjects to be presented and discussed:

Education and Training; Central Station Power; Fuels; Management; Wood Industries; Hydraulic; Machine-Shop Practise; Oil and Gas Power; Railroads; Industrial Power; and Materials Handling.

Trip to West Point on May 12, 1927

Members and guests of the Engineering and Chemical Societies in the New York City District are invited to participate in a special trip to West Point arranged under the auspices of the National Defense Division of the American Society of Mechanical Engineers. The *Alexander Hamilton* of the Hudson River Day Line has been chartered for the occasion and will make the trip to West Point on Thursday, May 12, 1927. The number of passengers will be limited to one-third capacity of the boat, in order to insure the comfort of all. On reaching West Point the party becomes the guests of Brigadier-General Merch B. Stewart, Superintendent. A close survey of the Academy will be permitted. There will be special drills, followed by an evening parade in full-dress uniform. Luncheon and dinner are included in the charge for the trip, which is $5.00 per person. Ladies are cordially invited to participate. Boat will leave West 42nd Street Pier at 10 a. m. and West 129th St. Pier at 10:20 a. m. Return trip will leave West Point at 7 p. m. arriving New York at 10 p. m. Send your reservations and make out checks to I. L. Martin, 29 West 39th St., New York City. (A. S. M. E. headquarters.)

Chamber of Commerce to Deliberate Water Power

Water as a source of power and a source of destruction, will figure largely in the deliberations of the 15 Annual Meeting of the Chamber of Commerce of the United States, to be held in Washington May 2-5.

What can be done to prevent the distressing floods which are now harassing the Middle West, and what practical use can be made of water power developed at Muscle Shoals and Boulder Canyon, are some of the questions which will be discussed.

The importance of the conservation and development of natural resources will be emphasized by Milton E. Marcuse, of Richmond, Virginia, who has represented the Natural Resources Industries on the directorate of the National Chamber for the past four years. W. H. Onken, Editor of the *Electrical World*, will speak on The Hydroelectric Power Era. Walter Parker, of New Orleans, will discuss Flood Control, and Charles Aubrey Eaton, U. S. Representative from New Jersey, will deliver an address on the Undesirability of Government Entering the Hydroelectric Power Field.

High-Voltage Conference

The fourth session of the International Electrical High-Voltage Conference will be held at Paris, June 23 to July 2. Honorary presidents are M. Blondel (France), C. O. Mailloux, past-president of the Institute (United States), G. Semenza (Italy), Honorary vice-presidents, M. Borquist (Sweden), S. Del Buono (Italy), President, M. Legouez (France); General Secretary, M. J. Tribot Laspiere (France). The United States delegation, organized by the U. S. National Committee of the International Electrotechnical Commission has the following working committee: C. O. Mailloux, chairman; Herbert W. Young, vice-chairman (Chicago); Frederic Attwood, (Paris); A. O. Austin (Barberton, Ohio); J. T. Barron (Newark, N. J.); H. W. Fuller (Chicago) and F. W. Peek (Pittsfield, Mass.). The first session will be on Production and Transformation of Energy; the second session on Construction of Lines and the third session on the Investigation of Central Stations and Networks.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, April 8, 1927.

There were present: President C. C. Chesney, Pittsfield; Vice-Presidents P. M. Downing, San Francisco; A. G. Pierce, Cleveland; W. P. Dobson, Toronto; H. M. Hobart, Schenectady;

Managers J. M. Bryant, Austin, Tex.; E. B. Merriam, Schenectady; M. M. Fowler, Chicago; H. A. Kidder, New York; I. E. Moultrop, Boston; H. C. Don Carlos, Toronto; F. J. Chesterman, Pittsburgh; National Secretary F. L. Hutchinson.

The minutes of the Directors' meeting held February 10, 1927, were approved as previously circulated.

The Board ratified the action of the Executive Committee, under date of March 25 1927, in approving applications for Student enrolment, admission to membership, and transfer from one grade of membership to another.

Reports were presented of meetings of the Board of Examiners held March 15 and April 5, 1927. Upon the recommendation of the Board of Examiners, the following actions were taken upon pending applications; 109 Students were ordered enrolled; 192 applicants were elected to the grade of Associate; 18 applicants were admitted to the grade of Member; 4 applicants were transferred to the grade of Fellow; 37 applicants were transferred to the grade of Member.

The Finance Committee reported approval for payment, of monthly bills for March amounting to $25,334.10, and for April amounting to $31,317.09, covering the usual routine items and the annual bills for the printing and binding of the Year Book. The Board ratified this action.

Upon application, and as provided in Article IV, Section 22, of the constitution, the Board voted that the following members be made "Members for Life" by exemption from future annual dues: G. Herbert Condict (on membership list 40 years), W. H. Freedman (37 years), Charles L. Clarke (43 years), and C. J. Goldmark (39 years).

Consideration was given to changing the date of the Annual Business Meeting of the Institute, now held on the third Friday in May each year, in New York, to a date during the annual Summer Convention, usually held during the last week of June, thus making probable a much larger attendance; and the Secretary was authorized to take the matter up further with the counsel of the Institute, in regard to the method of procedure in referring it to the membership for decision.

The President announced the appointment of the following members of the Committee of Tellers, to canvass and report upon the ballots received in the 1927 election of Institute officers: Messrs. E. S. Holcombe (Chairman), W. E. Coover, C. S. Demarest, R. R. Kime, C. D. Lindridge, Leland Stone, and John T. Wells.

Upon the recommendation of the Committee on Student Branches, the organization of a Student Branch of the Institute at Northwestern University, Evanston, Illinois, was authorized.

In accordance with the recommendation contained in a report of the Special Committee on Technical Activities, the Board authorized the creation of a new technical committee of the Institute, to be known as the Committee on Automatic Stations.

The nomination of a representative on the Engineering Division of the National Research Council, to serve for the term of three years commencing July 1, 1927, succeeding Mr. E. W. Rice, Jr., whose term expires on that date and who is ineligible for reappointment, was referred to the President with power. (This is a nomination, for appointment by the President of the National Academy of Sciences.)

Mr. L. A. Ferguson was reappointed a representative on the Commission of Washington Award, for the term of two years commencing June 1, 1927.

An invitation was accepted to send a delegate to the commemoration of the centenary of the granting of the Charter of King's College (now University of Toronto), in Toronto, on Thursday, October 6, 1927, and the two following days.

The Board approved a recommendation of the Standards Committee that the Institute apply to the American Engineering Standards Committee for sponsorship for Standards for Mercury Arc Rectifiers. Approval was also given to the recommendation of the Standards Committee that the Institute relinquish its joint sponsorship for Elevator Standards in favor of sole sponsorship by the American Society of Mechanical Engineers, provided such a course is satisfactory to the other sponsors.

In pursuance of the Standards policy adopted by the Board at its February meeting, calling for the reorganization of the Standards Committee, including nomination by other interests of Institute members for appointment to the Standards Committee, the following resolutions were adopted, incorporating in condensed form the organization of the Standards Committee as approved by the Board of Directors, and embodying an invitation to other interests to suggest members of the committee:

RESOLVED: That the Standards Committee, commencing June 1, 1927, shall consist of forty (40) or more members appointed by the President, as follows:

a. Ten (10) members representative of the electrical manufacturing interests;

b. Ten (10) members representative of the electric power, lighting, and railway interests;

c. Twenty (20) members at large selected by the President with a view to providing as far as practicable for adequate representation of all other interests.

Auxiliary members may be appointed by the President or the Board of Directors as may be deemed advisable for carrying on the work to the best advantage.

For proper coordination of standardization work, consideration shall be given to including representation of the various technical committees of the Institute and of the Institute's delegation on the American Engineering Standards Committee.

RESOLVED: That in pursuance of the long-established policy of the Institute that its Standards Committee shall fairly represent all groups and interests concerned, the President be authorized, in accordance with his recommendation, to invite other electrical societies to propose members of the Institute for appointment on the Standards Committee.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

Revision of Transformer Standards Suggested

A revision of Section 13, A. I. E. E. Standards for Transformers, Induction Regulators and Reactors has been proposed by the A. I. E. E. Technical Committee on Electrical Machinery. The revision consists in a proposed addition of two new rules Nos. **13-161** "Grounding Transformers" and **13-254** "Grounding Transformers." The text of the revisions is quoted herewith. Any suggestions or criticisms relative to this matter or bearing on any other part of Section 13 should be addressed to H. E. Farrer, Secretary, A. I. E. E. Standards Committee, 33 West 39th St., New York, N. Y.

13-161 Grounding Transformers.

(*a*) *Definition.* Grounding transformers are used solely for the purpose of clearing a short circuit or accidental ground of a transmission line by means of relays or otherwise.

(*b*) *Rating.* The rating of a grounding transformer shall be based upon the line voltage or terminal voltage during a ground if less than the line voltage, the frequency, the current in the ground circuit when one line becomes grounded, and the time the transformer must carry the current if longer than 60 seconds. Also if additional resistance or reactance is provided external to transformer the amount based on KVA (such as the KVA of a generator, etc.) should be stated.

13-254 Grounding Transformers.—Grounding transformers shall be capable while in service of withstanding a short circuit for a minimum specified time of 60 seconds.

For the purpose of standardization, 160°C. is set as the maximum permissible ultimate temperature at the end of the 60 second period based on a calculation of the temperature, assuming that all of the heat is stored in the copper and that the initial temperature of the copper is 75° C.

The increase in temperature during the short circuit

condition may be computed by the formula given in section 13-250.

If conditions should require that the time of short circuit exceed 60 seconds, or if the transformer is to be used also for power purposes, the case shall be considered as special.

Summer School For Engineering Teachers

The Society for the Promotion of Engineering Education announces that a summer school for engineering teachers will be established and the first sessions held in the summer of 1927. The Carnegie Corporation of New York has appropriated funds to operate the school for one year.

This is an outgrowth of the extensive investigation of engineering education which the Society has been conducting for the past three years. The project was suggested by W. E. Wickenden, Director of the Society's Investigation, as a result of his study of a similar school conducted in England. It has been studied by the Society's Committee on Teaching Personnel under the chairmanship of Dean Charles H. Warren, of the Sheffield Scientific School of Yale University, and was formally recommended by that committee to be undertaken at as early a date as possible.

Two sessions of the school, of approximately three weeks duration each, will be held during the first year. Cornell University and the University of Wisconsin have been tentatively selected as sites, and negotiations have been opened with their authorities. It is expected that tuition charges will be limited to a nominal registration fee and that costs of meals and rooms will be low. The work of the school will center around the teaching of specific subjects of the engineering curriculum. Since that subject is fundamental to all branches of engineering, mechanics has been selected for the first session. The work will be divided into three principal divisions: a, The teaching of pure mechanics (analytic mechanics); b, the teaching of the applications of mechanics in related fields, and c, the exposition of methods of teaching in general. Morning sessions will be devoted to lectures, demonstrations and laboratory exercises designed to illustrate methods of presenting specific divisions of the subject. The organizations, content and scope of courses in mechanics will be discussed and methods of teaching presented by precept, example and lectures. Afternoon sessions will be devoted to group discussions and analyzing the morning's work. Evenings there will be lectures on general topics relating to engineering education and to recreation. The teaching staff will be selected from the foremost teachers of the engineering colleges and from among the faculties of Teachers' Colleges and Departments of Education of the Universities.

Bringing groups of the ablest and most promising younger teachers into association with leaders having different points of view and different methods of presentation, with adequate opportunity for free discussion, promises to be a forward step in teaching the basic subjects of the engineering curriculum. It virtually brings the school to the instructor, and assembles for his benefit, a staff of the leading teachers of engineering and educational method, and may well prove significant in the general field of higher education for the professions. At least for the first year, the school will be conducted under the general supervision of the Society's Board of Investigation and Coordination, which board is charged with the duty of conducting the general investigation of engineering education. Immediate supervision will be in the hands of H. P. Hammond, Associate Director of Investigation.

American Engineering Council

A NEW PLAN FOR FEDERAL PROJECTS

A plan framed by the nation's engineers to stabilize employment and industry through the advance planning of Federal projects involving public roads, rivers and harbors, and public buildings was presented by Lawrence W. Wallace of Washington, executive secretary of the American Engineering Council to the semi-annual meeting of the Academy of Political Science, held at the Hotel Astor, Friday, April 8. Huge sums can be saved, Mr. Wallace declared, by the establishment of a Department of Public Works and Domain to replace the present Department of the Interior, the structure of which he called outworn.

Within this Department, Mr. Wallace explained, the engineers propose to set up a Board composed of representatives from the various bureaus, the principal duty of the Board being to assist the Secretary of the Department to formulate a general long range public works program. "Through the efforts of such a Board," Mr. Wallace continued, "it is reasonable to expect that long range planning of all public works will be effected even though administrations change, new policies be developed and new alinements within the government take place. This Board, under the coordinated plan encompassed in the formation of a Department of Public Works and Domain, should be able so to project governmental construction as to have a most substantial influence in leveling business cycles. The potentialities of such a plan are made apparent when the extent of the expenditures for Federal construction is understood. The Bureau of Public Roads is now spending, and has spent for some years past, over $75,000,000 annually for the construction of public roads. During the next fiscal year, the Federal Government will spend over $60,000,000 on river and harbor improvements. As the result of a single authorization of Congress the Supervising Architect's Office, alone, will erect during the next six years $165,000,000 worth of Federal buildings. This money is to be expended at the rate of $25,000,000 per annum outside of the District of Columbia, and the balance of the annual allotment is to be spent in the District of Columbia. The foregoing and other large services will spend in the fiscal year ending June 30, 1928, in excess of $200,000,000, more than three-fourths of which will be for construction work.

"All of these expenditures will be made without consideration of the business cycle. The trend of the supply and demand for material will not be given consideration for as much as six months in advance of the need. The matter of employment will scarcely be considered.

"Undoubtedly the expenditures to be made for the erection of federal buildings, highways, and river and harbor improvement are justified. We hold, however, that it is exceedingly unfortunate that the Federal Government has not provided means whereby a considerable amount of such appropriations could be retained until such time as business conditions became so depressed as to threaten a large degree of unemployment; then release it for public construction.

"In addition to approximately $150,000,000 to be expended by the Federal Government during the next fiscal year for the construction of public works, a tremendous volume of public works construction will be done by the states. According to conservative estimates the states spent between $300,000 000 and $500,000,000 for such purposes in 1925. The total expenditure by the Federal and State Governments is a very appreciable percentage of the entire construction volume in any year. In 1925 an aggregate of $5,000,000,000 was so spent. The Federal Government has no control over the expenditures of the States.

It is believed, however, that if the Federal Government should set an example of utilizing its expenditures for public works construction as a means of leveling the business cycle that the several states and municipalities would, in time, do likewise. Certainly if an appreciable amount of Federal, State and municipal expenditures for public works construction were taken off the top of a boom and placed in the trough of a depression, it would materially alleviate the serious consequences of such business depression, and the procedure would be far more sensible and wholesome in its influences than unemployment doles, or unemployment insurance, or bread lines. It would enable public works of every kind to be constructed at a lower cost, because, in periods of depression, price levels are lower than in boom times. Thus the masses would secure comfort and enjoyment in a greater measure and with greater ease, as taxes need not be so high. Even the advantages cited may not be the most valuable results of long range planning. The mere fact that it would be known that a money reservoir of large proportions would be tapped at the first significant sign that a business depression was about to ensue would have a tremendous psychological effect. It is well known that the attitude of mind has a good deal to do with the starting of a depression as well as with the depths to which it goes. We have learned such a lesson in connection with our banking system. Good banking principles demand adequate bank reserves. The Federal Reserve Bank, in addition to its actual cash reserve, imparts confidence in our national banking system by its very existence. Soon after its creation it wielded a tremendous influence in removing fear of financial difficulties."

RADIO DISCUSSED

The hearings held by the Federal Radio Commission were largely attended by representatives of broadcasting stations, manufacturing companies, engineers and others. As a result of this hearing, the Commission has already been able to partially develop a program which it is contemplated will prove beneficial to the greatest number of those concerned.

American Engineering Council's Radio Committee presented a statement on the engineering principles characterized by many of those in attendance at the conference as the most outstanding contribution to the work of the Commission. This report became the subject of much favorable comment and discussion.

One of the outstanding recommendations contained in the report opposed the widening of the wave band beyond the allotted frequencies now in use, namely 550 to 1500 kilocycles. Within a few days after the hearing the Commission decided that no change would be made.

The Commission is rapidly progressing with the work of issuing permits to stations in the United States. Over 100 such licenses were granted prior to April 15.

Commissioner William H. G. Bullard, upon his arrival in the capital about the middle of April, stated that it would be his policy to see that the interests of listeners came first in the work of the Commission of which he is the head.

The following prominent engineers prepared the report for American Engineering Council and submitted it to the Radio Commission: Calvert Townley, of the Westinghouse Electric and Mfg. Company; Dr. J. H. Delinger, chief of the Radio Laboratory of the Bureau of Standards; Dr. Alfred N. Goldsmith, of the Radio Corporation of America; Prof. C. Moreau Jansky, Jr., of the University of Minnesota; R. S. McBride, consulting engineer; David Sarnoff, of the Radio Corporation of America; Melville Eastham, of the General Radio Company, and Ray Manson, of the Stromberg-Carlson Company.

Standard Volt Sought by United States

The United States Bureau of Standards is starting to renew interchanges with other governments with respect to the standard cells in an effort to maintain uniformity in electromotive standards throughout the world.

This country, Great Britain, Japan, France, Germany and Russia are already in agreement to within a millionth of a volt as to standards of electromotive force. The present effort is for the purpose of establishing even more accurate comparison and to bring other countries to a recognition of the same standards. The complete report issued by the Chief of Electro-chemical Section, Division of Electricity, Bureau of Standards goes into detail as to the many years of effort in this direction, the attitude of various countries toward the movement, and its commercial significance.

Australian Commission Tours United States

An Australian Mission has arrived in the United States to make a two-months' tour of the industrial cities of the east and middle west, according to information obtained at the Department of State on April 11.

The mission is charged with "making a thorough and faithful investigation of the methods employed in, and the working conditions associated with the manufacturing industries of the United States, and to report thereon" under the following specific heads:

Methods making for greater efficiency in plant management; hours of labor, working conditions, wages and the adjustment of wages to fluctuations in the cost of living; piece work and conditions; efficiency of workmen and output per individual; power employed, particularly in regard to the use of electricity; standardization and mass production and the use of automatic machinery; costing systems; apprenticeship and child labor in factories; efficiency in management and supervision; relations between employer and employee; profit sharing, efficiency bonuses and inducements offered to employes to invest savings in the industries in which they are employed; social welfare and hygiene in large industrial establishments; governmental and private industrial statistical methods; technical education in relation to secondary industries.

Relation of State Rights to Muscle Shoals

Under the instructions of President Coolidge and at the request of Senator McNary, Chairman of the Senate Committee on Agriculture, a study of the legal problem of the relation of Federal and State ownership rights at Muscle Shoals is being made by the Department of Justice. The opinion of the Department is desired preparatory to bringing the subject before Congress early in the next session. This action is taking a view in the state of Alabama contention that it is the owner of all rights subject only to Federal use for navigation and national defense. The contentions of the state are set forth in a letter from the Governor of Alabama in which it is announced that the matter will be submitted to the summer session of the Alabama Legislature for the purpose of safeguarding the State's interest.

ENGINEERING FOUNDATION

MANUAL ON ENDURANCE OF METALS UNDER REPEATED STRESS

In 1919, National Research Council, University of Illinois, and Engineering Foundation joined forces for a new attack upon the old problem commonly known as Fatigue of Metals. The Council appointed an advisory committee; the University provided the director, staff and facilities for the research, and the Foundation supplied a substantial fund to pay for special equipment. A number of industries cooperated by contributing funds, materials and information. While this investigation has been progressing, several others have been conducted by Government bureaus and by industries, with little, if any, wasteful duplication. Large additions have been made to knowledge of

this subject, but the reports were scattered in numerous scientific and engineering publications, and some results have not been printed. There were requests, therefore, to have the information collected, condensed and put into a form convenient for use by engineers.

Engineering Foundation undertook to meet the need by asking Professor H. F. Moore, in charge of the investigation at the University of Illinois, to draft a brief summary, or manual, and by inviting several other investigators to examine the draft and make changes or additions. All responded most generously. The Foundation, consequently, is able to present in this small book, an up-to-date statement of knowledge of Fatigue of Metals in a form which, it is hoped, will prove useful to designing, operating and testing engineers.

The book will be 5 in. by 7½ in., bound in cloth with stiff boards. It summarizes the results of seven years of experimental investigation of the Fatigue of Metals at the University of Illinois under the auspices of the University, the National Research Council and Engineering Foundation, with the cooperation of several industries. Information from several other investigations has also been incorporated. It was compiled by H. F. Moore, D. Sc., Research Professor of Engineering Materials, in Charge, Investigation of Fatigue of Metals, University of Illinois, with the Cooperation of J. A. Capp, Chief of Testing Laboratory, General Electric Company, Schenectady, N. Y.; Alfred V. de Forest, Research Engineer, American Chain Company, Bridgeport, Conn.; H. C. Dickinson, Chief, Heat and Power Division, U. S. Bureau of Standards, Washington, D. C.; F. P. Gilligan, Secretary-Treasurer, The Henry Souther Engineering Company, Hartford, Conn.; Zay Jeffries, Consulting Metallurgist, Aluminum Company of America, Cleveland, Ohio; D. J. McAdam, Jr., Superintendent, Metallurgical Division, U. S. Naval Research Laboratory, Bellevue, Anacostia, D. C.; Charles A. McCune, Director of Research, American Chain Company, Bridgeport, Conn.; R. R. Moore, Chief, Physical Testing Branch, War Department Air Service, Engineering Division, McCook Field, Dayton, Ohio; F. E. Schmitt, Associate Editor *Engineering News-Record*, New York. The price, postpaid, is $1.00, and ready for delivery in May. Orders and remittances should be sent to Engineering Foundation, 29 West 39th Street, New York.

College Course in Meters

Utility experts are to lecture at the University of Michigan in another course of instruction for men in the public utility industry which will begin this Spring at the University with classes in electric metering by Professor Benjamin F. Bailey, Department of Electrical Engineering. Laboratory conferences and laboratory tests are included.

The purpose of the course is to assist electric utilities in training men who install test and maintain meters. It is conducted by the University in cooperation with the Michigan Public Utilities Commission and the Michigan Light Association.

Ninety-Mile Welded Pipe Line

A description of the California ninety-mile welded pipe line will be given by Prof. L. T. Jones of the University of California at a meeting of the American Welding Society in the Engineering Building, 33 West 39th Street, New York, N. Y., at 8:00 p. m., Tuesday, May 17, 1927. Some interesting facts developed in the construction of this line and while articles have appeared before descriptive of the work, all the facts have never been brought out. As this is a matter of wide interest to engineers, the American Welding Society extends a cordial invitation to all members of the A. I. E. E. and any others interested to be present.

PERSONAL MENTION

Charles F. Gray, who has been carrying on a consulting engineering practise at Miami, Fla., has removed his activities to Winnipeg, Canada.

E. S. Lincoln, consulting engineer, has discontinued his office at Portland, Maine and is now located in offices in the new Graybar Building, New York, N. Y.

O. M. Hovgaad has resigned his position in the division of research and development of the Acme Apparatus Company and is now associated with the Briggs & Stratton Corporation, Milwaukee, Wis., as radio research engineer.

Wisner R. Townsend, on April 1st, joined the engineering staff of Baker and Spencer, Inc., 117 Liberty Street, New York City. Mr. Townsend was formerly in the Engineering Department of McClellan and Junkersfeld, Inc.

R. E. A. Putnam has returned from Tokio, Japan, where he has been with the Nippon Electric Company, Ltd., to take a position with the International Standard Electric Corporation, New York, N. Y.

H. R. King, who, since 1921, has been general sales manager for M. S. Wright Company, Worcester, Mass., has been made vice-president and general sales manager of the Conlon Corporation, Chicago, Ill.

W. H. Patterson, formerly Assistant Industrial Sales Manager, of the Westinghouse Electric & Manufacturing Company, has been appointed district manager of the Kaestner & Hecht Company, with offices in the Chamber of Commerce Building, East Pittsburgh, Pa.

Earl J. Biegel has just been made assistant superintendent of the electric distribution department of the Memphis Power & Light Company, Memphis, Tenn. Prior to this appointment, Mr. Biegel was chief division inspector for the Westchester Lighting Company, Mount Vernon, N. Y.

Olindo O. Ceccarini, on March 19th, resigned from the position of radio engineer with the Bell Telephone Laboratories and is at present connected with the Vitaphone Corporation, making his residence in Hollywood and working as direct assistant to Col. N. H. Slaughter who is in charge of the Hollywood Studio.

Charles E. Krause, having resigned his position as Assistant Professor of Electrical Engineering at the Oklahoma A. and M. College, has accepted appointment as supply engineer in the Supply Engineering Department of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

H. S. Sands, Vice-president of the Institute and for many years associated with the Westinghouse Electric & Manufacturing Company, Denver, Colo., has just opened his own consulting engineering offices, in the First National Bank Building, of that city.

Wm. H. Baker and C. G. Spencer announce the organization of the firm of Baker and Spencer, Incorporated, for the general practise of engineering and construction at 117 Liberty Street, New York City. Mr. Baker and Mr. Spencer are both Cornell graduates and posses broad experience in the electrical field.

J. Stanley Brown, on April 1st, joined the engineering staff of Baker and Spencer, Inc., New York, N. Y. His previous connection was with McClellen & Junkersfeld, Inc., where his duties were of a general nature both on design in the main office and on construction engineering and superintendent in the field. His new work will also be along general lines.

W. C. Kalb, who, since the merging of the Corliss Carbon Co. with the National Carbon Co., Inc., has been superintendent of the Corliss Works of the National Carbon Co., Bradford, Pa., was transferred February 1st to the Carbon Sales Division of the National Carbon Co., Inc., at Cleveland, Ohio, as consulting engineer.

Samuel Schneider has opened offices at 1225 Broadway, New York City under firm name of Harry Schneider Co., where he will represent electrical manufactures in lighting fixtures,

appliances and labor saving devices. Mr. Schneider has been engaged in the electrical construction and inspection field for the past 20 years.

W. D. WILKINSON has assumed his new duties as engineer in the commercial department of the New England Power Co., with headquarters at Worcester, Mass. Mr. Wilkinson has been with the Utica Gas & Elec. Co., at Utica, N. Y., since 1920, as superintendent of the meter and testing departments and later as electrical engineer. He joined the Institute in 1920.

W. C. CHAPPELL, because of ill health contracted during the world war, has at the suggestion of his medical advisor, been obliged to resign from his work in the Engineering Dept. of the Electric Bond and Share Co., New York, N. Y. Mr. Chappell has been an Associate of the Institute ever since 1910. His service to his Company has been of extremely high caliber and his forced retirement is deeply regretted.

IRA DYE was appointed recently to the position of assistant superintendent in charge of maintenance and repair of the Shell Co. of California's fleet of cars and trucks for Oregon, Washington, Idaho and British Columbia. His duties include specification and design of bodies and special equipment for automotive units used in the distribution of petroleum products through the area indicated by the states mentioned.

D. S. WEGG became associated with the Electric Bond & Share Co. on April 1st when he resigned from the Department of Commerce in Washington where he had been Assistant Chief of the Electrical Equipment Division for over two years. In his new work he will be concerned with economic and engineering problems effecting the various foreign properties of the Electric Bond & Share Co. His headquarters will be in New York.

R. A. LANGWORTHY, formerly associated with the firm of Dwight P. Robinson & Co., Inc., has accepted an election as Vice-President and General Manager of the Ruths Accumulator Co., Inc., New York City. After a broad experience of 25 years with such firms as Stone & Webster, Federal Power and Light Co., American Engineering Co., Meiklebam & Dinsmore, and Ford, Bacon & Davis, Mr. Langworthy has decided to devote his entire time to his new activities.

ELMER A. SMITH a Member of the Institute was recently elected an Honorary Member of the Paris Academy of Literature for important contributions to literature, arts and sciences. In 1925, he was made Fellow of the Royal Society and was the first American to receive the signal honor for investigating natural lightning, (in the National Institution of Switzerland in 1926) and for sciences and mathematics (Royal Society of Belgium, March 1927).

LEON C. HERRMANN has severed his connections with the Westburg Engineering Company of Chicago, (representatives for the Weston Electrical Instrument Company of Newark, N. J. and the Ward Leonard Electric Company) with whom he has been for the past thirteen years in the capacity of Secretary. He is now engaged in business for himself as district representative of the American Transformer Company of Newark, N. J. and the Indiana Manufacturing & Electric Co. of Marion, Indiana.

WILLIAM F. DURAND, past president of the American Society of Mechanical Engineers and member of the Institute since 1912, was recently named by the Secretary of the Interior to serve on the Colorado River Commission. This is a group of five men chosen to make a cursory survey of the levies and delta country of the Lower Colorado, view the Boulder Glen ferry, and other points of interest, in order to report to Congress the essential features of the Swing-Johnson bill. The potential uses of the Colorado River, its menacing possibilities, the interstate and international rights to its use will form the important features of the report.

M. E. SKINNER has recently resigned as Commercial Manager of the Duquesne Light Company at Pittsburgh to accept similar responsibilities with the Mohawk & Hudson Power Corporation, which controls the operation of the Utica Gas & Electric Company, Fulton County Gas & Electric Company, Adirondack Power & Light Corporation, Troy Gas Company, Cohoes Power & Light Company, Municipal Gas Company of Albany, Central New York Power Corporation, Syracuse Lighting Company, and Eastern New York Utilities Company, operating through the Mohawk and Hudson Valleys from Syracuse to the New York State line. His new headquarters are at Albany, N. Y.

Mr. Skinner has taken active part in the Institute work, having served both as National Chairman of the Membership Committee and Chairman of the Pittsburgh Section. He has also contributed generously to the technical press, including several papers on transformer design presented before the Institute. He is a member at large of the Commercial Section Executive Committee of the National Electric Light Association, and was recently appointed Chairman of the Subcommittee on Utilization of the Electrical Apparatus Committee. He is also active in the work of the Pennsylvania Electric Association, having served consecutively as Chairman of the Commercial Section, Treasurer, and a member of the Executive Committee with office as Vice President of the Association. He was also among the winners of Bonbright Prize. Mr. Skinner is a member of the Pittsburgh Chamber of Commerce, Pennsylvania State Chamber of Commerce and the Electric League of Pittsburgh.

GRAHAM BRIGHT, consulting engineer, Pittsburgh, Pa. has been appointed sales engineer in charge of the Edison Storage Battery Mine Lamp Division of the Mine Safety Appliances Company, Pittsburgh, Pa. Mr. Bright was formerly associated with the Westinghouse Electric & Mfg. Co., in charge of industrial and mining engineering applications, and for the past three years, has been a member of the firm of Howard N. Eaverson & Associates, in charge of Power Applications. He was elected to the grade of Fellow by the Institute in 1922, is a member of its Technical Committee on Applications to Mining Work and chairman of the Pittsburgh Section of the American Institute of Mining and Metallurgical Engineers.

Obituary

Le Roy Clark, president and director of the Safety Cable Company and a prominent figure in the wire and cable industry for many years, died suddenly April 18 at Falmouth, Mass. His entire business career had been with the Safety Cable Company and its predecessor, the Safety Insulated Wire & Cable Company, which he joined as an electrician a year prior to his graduation from college. Subsequently he became electrical engineer for the company, and upon its reorganization in 1902 he was made vice-president. Four years later he was promoted to the presidency.

Under the leadership of Mr. Clark, as chief of the wire and cable section of the finished products division of the War Industries Board, the insulated wire and cable industry made an enviable war record. When American wire manufacturers were called upon to help supply the war demands, the wire industry, organized and directed by Mr. Clark, accomplished wonders. Mr. Clark was first chairman of the wire and cable section of the Associated Manufacturers of Electrical Supplies and was at the time of his death chairman of the wire and cable section of the National Electrical Manufacturers' Association and a member of its committee on policy relations with other organizations, a sub-committee of the policy committee. Mr. Clark joined the Institute in 1894.

Thomas Dixon Lockwood, inventor, Patent Attorney for the American Telephone & Telegraph Company and Charter Member of the Institute, died at his home, Melrose, Mass., April 6, 1927.

Mr. Lockwood was born in England December 30, 1848. When he was still a boy, his parents moved to Port Hope, Ont., Canada and there he became the first operator for the Provincial Telegraph Company. He later held several executive offices in the Bell Telephone Company, in which he became interested

July 1879. From that date until 1881, he was the National Bell Telephone Company's assistant general inspector and from 1881 on, he had been in charge of their patents department. He was an advisory electrician and engineer for the Bell Telephone of Canada from 1880 to 1890 and from 1882 to 1911 was advisory expert of the Western Electric Company. He was also expert of the patent and technical information department of the American Bell Telephone Company. For his work with the American Telephone and Telegraph Company, his headquarters were in Boston. He was consulting professor of telephony, telegraphy and patent practise at the Brooklyn Polytechnic Institute, patent solicitor and expert in electrical inventions before the Patent Office and in the United States Courts. Beside being one of the first members of the Institute Mr. Lockwood was a member of the Institution of Electrical Engineers of Great Britain, a foreign Life Fellow of the Imperial Institution of London, an honorary member of the National Electric Light Association, an honorary member of the Association of Railway Telegraph Superintendents and a member of the Canadian Electrical Association. His contributions to the technical press have been liberal and he was also the author of a number of books on electrical subjects, among them, "Translation and Revision of Ohm's Law," in 1890.

Edgar Wilkins, electrical engineer for the Frank & McLaughlin & Co., Inc., Mexico, was kidnaped and shot by Mexican bandits according to note received by the Department of State April 6, Aaron Saenz, Mexican Minister for Foreign Affairs. Mr. Wilkins and his little son were captured and held for a $20,000 ransom, the child being sent back with the demand to the government, but his father was found to have been killed before return could be made. Mr. Wilkins was born in Savannah, Ga., January 19, 1876. He was educated in the Southern schools and his first work in the electrical field was in 1893, when he joined the forces of the Electric Supply & Construction Company, Savannah, in the capacity of wireman. His promotion in responsibility was rapid and after serving in some half dozen capacities, 1902 found him engineer in charge of an ice plant and electric light plant. Mr. Wilkins joined the Institute in 1906 as an Associate.

Charles William Holtzer, a much respected and leading resident of Brookline, Mass., and chairman of the Board of Directors of The Holtzer-Cabot Electric Company, Boston, Massachusetts, died after a long illness the week of April 7, 1927.

Mr. Holtzer was born in Karlsruhe, Germany and attended private schools and the Institute of La Fontaine. After completing his education there, he served his apprenticeship as a machinist in Germany and came to the United States in 1866. He was then but 18 years of age. Arriving in New York, he went to Boston where, for the next two years, he engaged in experimental work on artillery ammunition, particularly in connection with the timing of projectiles. Following this, he was several years in the employ of E. S. Ritchie & Sons, makers of philosophical instruments. In 1874 Mr. Holtzer engaged in the manufacture of simple electrical devices in cooperation with Mr. Newell under the firm name of Holtzer & Newell, a little later establishing a small business of his own, still dealing in electrical apparatus. During this latter period, Mr. Holtzer operated the first suburban telephone exchange outside of Boston with 14 subscribers. He was a natural executive, ingenious and original in his ways of winning the loyalty of men and inspiring them with his own faith and enthusiasm. He was most appreciative of work well done, and "did not bargain with life for a penny." His philanthropic activities were most unobtrusive but very wide in extent. He was director of the Brookline Trust Company and a trustee of the Brookline Savings Bank. He was a member of the Boston Chamber of Commerce, the German Aid Society, Massachusetts Charitable Mechanics Association, the Boston Society of Arts, the Verein Deutcher Electrotechniker, the Boston City Club and the Engineers Club. He was also a 32d degree Mason and member of the Shrine and the Knight Templars. Mr. Holtzer joined the Institute in 1903.

Clark A. Sutton, lately elected an Associate of the Institute and since his return from service in the Signal Corp and Air Service at the time of the World War, with the Bethlehem Steel Corporation, died on April 1, 1927.

Mr. Sutton was born at Reading, Pa., October 17, 1899. He had one year of High School at Quakertown, Pa., two years at Stevens Trade School, Lancaster, Pa. and 8 months in the United States Veteran's Bureau, Vocational Training. His work with the Bethlehem Steel Corporation was in both the Shipbuilding Dept. and the Mining Dept.

Albert J. Hoch, equipment engineer for the New York Telephone Company, died March 15, 1927, at East Orange, N. J. Mr. Hoch was a native of Brooklyn, New York, where he had attended a course in Applied Electricity at Pratt Institute. From 1906-10, he was plant engineer for the New York Telephone Company, then went into the Engineering Dept., where he cared for the preparation of plans and specifications for Central Office and private Branch Exchange switchboards. His E. E. was won by an evening course which he took at the Brooklyn Polytechnic Institute. Mr. Hoch joined the Institute in 1918.

James C. Webster, at one time in the Research Laboratory of the National Carbon Company, Inc., Cleveland, Ohio, but of late serving their Ontario interests in the capacity of sales engineer, died suddenly of pneumonia February 4, 1927. Cleveland was his native city, and there he also attended the Shaw High School at East Cleveland, following it with courses at Adelbert College, Western Reserve University, obtaining his A. B. in 1912. He attended Columbia University Graduate Engineering Schools, and won a degree in chemistry. Mr. Webster became an Associate of the Institute in 1917.

Svatopluk Sychra, of the engineering staff of Ceskomoravska-Kolben, Czechoslovakia, died suddenly January 7, 1927. Mr. Sychra attended public and High School at Prague, afterwards took a course in Electrical Engineering at the University of Prague. From 1915-1918, he was in the military service of the Railway Engineering Dept.; 1918 to 1919 in the Engineering Dept. of the Krizik Electrical Works, Prague and in 1919 entered the general engineering department of his present company. He was characterized as a "faithful and competent worker." He had belonged to the Institute since 1924, when he joined as an Associate.

Washington Devereaux, supervising engineer of the Philadelphia Fire Underwriters' Association, died at his home, Philadelphia, on April 18, 1927. Mr. Devereaux joined in the Institute in 1906. He was born in Philadelphia February 9, 1863 and in 1878 graduated from Girard College. Afterwards he pursued his education by the study of various text books and a course in the International Correspondence Schools. In June 1880, he took a position with the Bell Telephone Company of Philadelphia, with which company he remained until 1882. From August 1882 to August 1884 he was inspector of the Central Penn Telephone and Telegraph Company, in charge of the Bloomsburg Division and office duties consisting of the superintending of construction of lines, installing exchanges and general repairs to the system. He then returned to the employ of the Bell Telephone Company of Philadelphia, to engage in the con struction of multiple switch board, instrument repairs, and cable work, remaining with them for three years. In 1887 he was placed in charge of the electrical equipment of Girard College; then for one year, he was doing general work. April 1888 found him busy with the Juragua Iron Company in the rebuilding of telephone and telegraph systems from Santiago to Siboney and Firmeza, and in 1889, he joined the Fire Underwriters Association as electrical inspector for Philadelphia. He was transferred to the grade of Member in 1919. Mr. Devereaux will be greatly missed by his professional as well as his business friends.

Arthur Keller, electrical engineer of the Pawling & Harnischfeger Co., Milwaukee, Wis., and an Associate of the Institute since 1904, died Saturday, March 12, at his home in Milwauke. Mr. Keller was born in Switzerland in 1882, had been connected with the Harnischfeger Corporation for the last twenty years and during that time had perfected much of the electrical equipment that goes into its cranes. Mr. Keller was educated at the Universities of Zurich and Bien in Switzerland and was employed by some of the largest electrical manufacturers in this country as well as in Europe before he joined the Harnischfeger Corporation. He was a member of the Association of Iron and Steel Electrical Engineers.

Jesse Merrick Smith, retired consulting engineer, President of the American Society of Mechanical Engineers in 1909 and Charter Member of the Institute, passed away on April 1 at his home in New York City, at the age of seventy-eight.

Mr. Smith was born in Newark, Ohio, October 30, 1848, the son of Henry and Lucinda Salisbury Smith. After studying at Philo Patterson's School in Detroit, he entered the Rensselaer Polytechnic Institute at Troy, New York, in 1865, and from there went to the Ecole Centrale des Arts et Manufactureres, Paris, receiving the M. E. degree in 1872. On his return to the United States he entered professional work in the Hocking Valley, Ohio, building blast furnaces and coal mines. He remained at this work until 1880, at which time he opened a consulting engineering office in Detroit, Michigan, and devoted his time to designing special machinery as well as manufacturing and power plants in connection with manufacturing establishments. During the latter part of his consulting work in Detroit he entered the field of patent litigation and became an expert in a number of important suits. In 1898 he moved from Detroit to New York, in which city he opened an office as a consulting engineer and expert in patent litigation. Mr. Smith took an important part in the dedication of the Russell Sage Laboratory of Mechanical and Electrical Engineering at the Rensselaer Polytechnic Institute. He was a member of the American Institute of Mining and Metallurgical Engineers, president of the American branch of the Alumni of the Ecole Centrale, and as a graduate of this celebrated school he became a member of the Societe des Ingenieurs Civils de France.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify the Institute Headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

Carl H. Menke, 1013 Palean St., Keokuk, Iowa.
Julius Ronay, c/o American Steel & Wire Co., Donora, Pa.
C. M. Stayner, Pocatello, Idaho.

Past Section Meetings

SECTION MEETINGS

Akron

Starting of Large A-c. Motors, by P. C. Jones, Goodyear Tire and Rubber Co. March 18. Attendance 84.

Boston

Electricity in Transportation, by W. B. Potter, General Electric Co. Joint meeting with A. S. M. E. and A. S. C. E. March 23. Attendance 250.

Chicago

Our Debt to Scientific Research, by C. C. Chesney, National President, A. I. E. E. Dinner Dance. March 11. Attendance 200.

The Mechanical Analogy of a Transmission Line, by R. D. Evans, Westinghouse Electric & Mfg. Co. April 5. Attendance 300.

Cincinnati

Radio Activities at the University of Cincinnati, by W. C. Osterbrock, University of Cincinnati. Slides and motion pictures were shown. February 10. Attendance 100.

Chromium Plating and Its Applications, by Dr. Wm. Blum, Bureau of Standards. Joint meeting with A. S. M. E., A. S. S. T., A. C. S., American Electroplaters Society and American Electrochemical Society. March. 24. Attendance 300.

Cleveland

The Engineering Essentials of Traffic-Control Systems, by C. E. Egeler, National Lamp Works;

The Place and Value of Signals in Traffic Control, by M. A. Bleeke, Deputy Traffic Commissioner;

What Traffic Control Means to the Automobile Driver, by John McChord, Former Chief Counsel, Cleveland Automobile Club, and

Installation and Operation of Traffic-Control Systems, by M. W. Garnett, City Engineer. Joint meeting with I. E. S. March 24. Attendance 210.

Power System Stability, A Mechanical Analogue, by C. L. Fortescue, Westinghouse Electric & Mfg. Co. Demonstrated. April 7. Attendance 110.

Columbus

The Future of Urban Transportation, by Dr. Wm. McClellan, McClellan & Junkersfeld, Inc. March 25. Attendance 87.

Connecticut

Engineering and National Progress, by D. S. Kimball, President American Engineering Council. March 22. Attendance 65.

High-Pressure Gas and Its Possible Competition with Electricity, by W. D. Stewart, Stone and Webster Co. In the afternoon an inspection trip was made to the new gas plant of the Stamford Gas and Electric Co., and was followed by a dinner. April 5. Attendance 111.

Denver

Steel-Tank Mercury Arc Rectifiers, by C. A. Butcher, Westinghouse Electric & Mfg. Co. March 21. Attendance 27.

Detroit-Ann Arbor

Refrigeration, by A. W. Berresford, Past President, A. I. E. E., and John Wyllie. Joint meeting with A. S. M. E. March 15. Attendance 150.

Erie

Power House Design, by P. H. Harris, Pennsylvania Public System. March 22. Attendance 68.

Fort Wayne

Insulating Varnishes, by Howard Miller, General Electric Co. A motion picture, entitled "Behind the Pyramids," was shown. March 17. Attendance 30.

Indianapolis-Lafayette

Up-to-date Boiler-Room Practise, and the Use of Powdered Coal, by Alex. D. Bailey, Commonwealth Edison Co. March 1. Attendance 40.

Factors in the Development and Application of Electric Light, by Prof. A. N. Topping, Purdue University. April 8. Attendance 24.

Ithaca

Research in Electrical Engineering, by C. C. Chesney, National President, A. I. E. E., and

Research and Research Men, by C. F. Kettering, General Motors Corp. March 18. Attendance 300.

Louisville

Electrically-Driven Tools, by W. W. Crooker, Jas. Clark, Jr., Electric Co. An inspection trip to the plant of the Jas. Clark, Jr., Electric Co. was made. March 8. Attendance 42.

Lynn

Electricity and the Steel Industry, by L. A. Umansky, General Electric Co. Illustrated with slides. March 16. Attendance 54.

The Romance and Tragedy in Modern Horticulture, by E. L. Farrington, Mass. Horticultural Society. April 11. Attendance 250.

Nebraska

Electric Railway Problems, by L. S. Storrs, A. E. R. A. March 14. Attendance 45.

Electrical Street Railways and Bus Service, by L. S. Storrs, A. E. R. A. A dinner preceded the meeting. March 15. Attendance 75.

New York

Your Outlook, by Dr. Willis R. Whitney, Director, Research Laboratory of the General Electric Co. Announcement was made of the election of the following officers for the coming year: Chairman, L. W. W. Morrow: Secretary-Treasurer, J. B. Bassett. April 8. Attendance 400.

Niagara Frontier

Changing the Voltage of Transformers under Load, by L. H. Hill, Westinghouse Elec. & Mfg. Co. Illustrated with slides. March 24. Attendance 62.

Philadelphia

The Spirit in Which to Work, by Dr. Francis H. Green, Pennington School for Boys. A short talk on the work of the A. I. E. E. was also given by Mr. H. H. Henline, Assistant National Secretary. March 31. Attendance 184.

Armor-Clad Switch Gear, by H. B. Nye, Allis-Chalmers Mfg. Co. Illustrated with slides. April 11. Attendance 125.

Pittsburgh

Mercury Arc Rectifiers, by F. A. Faron, General Electric Co. A discussion on this subject was also given by Caesar Antonio, Chicago, North Shore and Milwaukee Railroad. April 12. Attendance 350.

Pittsfield

Explosions, by Thurman (Dusty) Miller, Humorist. Short talks on the A. I. E. E. were given by C. C. Chesney, National President, and H. M. Hobart, Vice-President, District No. 1. Annual Dinner. March 15. Attendance 239.

Forecasting in Business, by N. F. Hanley, General Electric Co. March 29. Attendance 78.

Portland

The Development of Water Resources with Full Protection for Fish, by J. E. Yates, Pacific Power and Light Co. March 17. Attendance 60.

Providence

The Engineer and National Progress, by D. S. Kimball, President, American Engineering Council. March 23. Attendance 75.

St. Louis

Railway Electrification, by Dr. W. B. McClellan, McClellan and Junkersfeld, Inc. Joint meeting with Engineers' Club of St. Louis. March 16. Attendance 135.

Saskatchewan

Signal Services in Peace and War, by Lieutenant-Colonel E. Forde, Assistant Director of Signals, Ottawa. March 16. Attendance 34.

Schenectady

Research Work in Automobile Building, by C. F. Kettering, General Motors Corp. Joint meeting with A. S. M. E. March 16. Attendance 400.

Influence of Indianapolis Water Case on Rate Making, by F. P. McKibben, Pennsylvania R. R. March 25. Attendance 150.

Seattle

Engineering Features of the Great Northern Railway Tunnel, by Col. Frederick Mears, Asst. Chief Engr.;

Tunneling Methods and Construction, by R. F. Hoffmark, A. Guthrie & Co., and

Electrification, by R. D. Booth, Consulting Engr. Illustrated with slides. Joint meeting with A. S. M. E., A. S. C. E. and A. I. M. E., preceded by a dinner. March 15. Attendance 400.

Sharon

Power-System Stability, by A. D. Dovjikov, Westinghouse Elec. & Mfg. Co., and

Stability from the Operator's Point of View, by F. H. Mayer, Southern California Edison Co. Illustrated. April 5. Attendance 135.

Spokane

Electricity on the Washington Farms, by H. L. Garver, Investigator of the Washington Committees on the Relation of Electricity to Agriculture. March 18. Attendance 19.

Springfield

The Engineer and National Progress, by D. S. Kimball, President, American Engineering Council. A short talk was also given by C. C. Chesney, National President, A. I. E. E. March 21. Attendance 48.

Toledo

A-c. Elevator Motor Drive, by E. B. Thurston, Haughton Elevator & Machine Co. March 18. Attendance 26.

Toronto

The Construction and Application of Air Brakes, by J. H. Wood, Canadian Westinghouse Co. February 25. Attendance 31.

Design and Operating Characteristics of Rotary Converters, by B. Ottewell, Canadian General Electric Co. Illustrated with slides.

High-Capacity Mercury Arc Rectifiers, by F. A. Faron, General Electric Co. March 11. Attendance 82.

Engineering Research, by W. B. Buchanan, H. E. P. C., and

Transformer Manufacture, by C. C. Chesney, National President, A. I. E. E. Illustrated with motion pictures. March 25. Attendance 171.

Urbana

Transatlantic Radio Telephony, by Arthur Oswald, Bell Telephone Laboratories, Inc. March 17. Attendance 135.

Piezoelectric Oscillations and Supersonic Vibrations, by Prof. J. T. Tykociner, University of Illinois. April 7. Attendance 104.

Utah

The Printing Telegraph, by M. M. Johnson. Illustrated. March 22. Attendance 85.

Vancouver

Description and Demonstration of Automatic Substation, by R. L. Hall, British Columbia Electric Railway Co., Ltd. March 1. Attendance 57.

Washington, D. C.

Electric Welding, by R. E. Wagner, General Electric Co. Illustrated. The meeting was preceded by a dinner. March 8. Attendance 200.

Worcester

Design and Manufacture of High-Voltage Transformers, by D. R. Dalzell, General Electric Co. February 24. Attendance 22.

The Engineer and National Progress, by D. S. Kimball, President, American Engineering Council. Joint meeting with A. S. M. E., A. S. C. E., Electric League of Worcester County, and A. S. S. T. March 24. Attendance 150.

A. I. E. E. Student Activities

CONFERENCE ON STUDENT ACTIVITIES AT BETHLEHEM, PA.

A Conference on Student Activities of the Middle Eastern District, No. 2, A. I. E. E., was held at Bethlehem, Pa., on Saturday, April 23rd, in connection with the Regional Meeting of that District held April 20-23.

Of the eighteen Branches in the District, nearly all were represented by their counselors and chairmen.

The Conference was opened by Vice-president A. G. Pierce, who introduced Professor H. B. Dates, Chairman of the District Committee on Student Activities, who presided during the presentation of the following program:

The Institute and the Student Branches, F. L. Hutchinson, National Secretary, A. I. E. E.

Resumé of Student Branch Activities of the Middle Eastern District No. 2, C. S. Ripley, Secretary.

How Does the Branch Serve the College? Prof. F. C. Caldwell, Counselor, Ohio State University Branch.

Methods of Stimulating Interest in Meetings, Prof. H. E. Dyche, Counselor, University of Pittsburgh Branch.

The Organization of the Student Branch, Prof. L. A. Doggett, Counselor, Penn. State College Branch.

Prof. B. C. Dennison, Counselor, Carnegie Institute of Technology Branch.

The Duties and Opportunities of a Counselor, Prof. T. J. MacKavanaugh, Counselor, Catholic University of America Branch.

Twenty-Five Years of Branch Activities, Prof. William Esty, Head of Department of Electrical Engineering, Lehigh University.

General Discussion of Student Activities.

Mr. Hutchinson discussed the early devélopment of the Student Branches, and said the chief purpose of them is to afford the Students practise in carrying on activities similar in nature to those carried on by Institute members, such as the presentation and discussion of papers, visits to places of engineering interest, etc. He said there is a tendency to drift away from the main purpose and have visiting speakers for too many Branch meetings, and that the number of meetings at which the time is occupied by visiting speakers should be very limited indeed. He also mentioned the reasons for the appointment of Counselors and other important phases of Student Activities.

Mr. Ripley's resumé of Branch activities in the District showed that practically all Branches have been fairly active during the present year.

Professor Caldwell said the Institute is giving valuable cooperation in instruction and that the connection of the Students with a national organization, the publicity in the JOURNAL, reports to headquarters, payment of the traveling expenses of incoming Branch chairmen to conferences, and the opportunities for contacts with engineers all arouse the pride and stimulate the loyalty of Students who participate in Branch activities.

Professor Dyche mentioned, as the best means of stimulating interest in meetings, debates, thesis reviews, talks on summer experiences, talks by recent graduates, and an annual banquet. The University of Pittsburgh Branch usually has three Student speakers on each program, and extemporaneous speaking is insisted upon.

Professor Doggett emphasized the importance of having Branch officers with good personality for their duties. He showed interesting curves of attendance at Pennsylvania State College Branch meetings beginning in 1923 and extending to the present. He thinks motion pictures, outside speakers, and professors are helpful in stimulating an inactive Branch, and that is about the only excuse for placing them on the programs.

Professor Dennison said it is a mistake to require attendance at Branch meetings and that every effort should be made to develop initiative and leadership. He suggested the use of prizes for the best membership records.

Professor MacKavanaugh compared a counselor with a personnel administrator, and said he is an agent of the Institute. As such he can help build up appreciation of the JOURNAL among his students.

Professor Esty discussed the origin of the provision for Student Branches, and the organization of the Lehigh University Branch in 1902. It was the first Branch authorized, and was organized by Professor Esty. He considers Branch activities extremely valuable in training for leadership, and mentioned several means of producing interest in meetings.

The Student representatives gave brief reports upon the activities of their Branches.

Professor Harold B. Smith, member of the Committee on Student Branches, gave a brief summary of the discussion, showing the great opportunities available to Branch members.

A resolution stating it to be the sense of the Conference that the major portion of the make-up of Branch programs should consist of Student speakers was passed unanimously.

The Committee on Student Activities decided that its officers should be a chairman and vice-chairman, and that there should be an executive council consisting of those officers, the District Vice-president, District Secretary, and the past chairman of the Committee, all to hold office one year, coincident with the Institute administrative year. It was decided that the past chairman should represent the Committee at the Sections and Branches Conference at the Summer Convention.

The following officers were elected: Chairman, Professor L. A. Doggett, Pennsylvania State College; Vice-chairman, Professor F. C. Caldwell, Ohio State University.

NEW YORK SECTION HOLDS STUDENT CONVENTION ELECTION OF OFFICERS FOR 1927-28 ANNOUNCED

The second annual Student Convention of the New York Section was held on Friday, April 8, 1927 in the Engineering Societies Building, 33 West 39th St., New York, N. Y.

Following the successful Student Convention of 1926, arrangements were made by the Student Committee in charge to have such a committee appointed from year to year to insure the proper and successful handling of future affairs. The plan proved eminently successful, as practically all arrangements for 1927 were made by this year's Student Committee, subject only to modification by conference with faculty members and New York Section officers. Eight colleges located in the New York Section territory took part in the meeting. They were: Columbia University, Newark College of Engineering, Cooper Union, College of City of N. Y., Rutgers University, Stevens Institute of Technology, New York University and Brooklyn Polytechnic Institute.

On Friday morning there were the students' inspection trips to the G. E. Lamp Works at Harrison, N. J., the Bell Telephone Laboratories, the U. S. Cruiser "Milwaukee" and the Kearney Power Station of the Public Service Electric & Gas Co. of N. J. Those participating in this trip were the guests of the Company at a luncheon served at the plant, reached by busses which the Power Company furnished.

An afternoon session held in the Engineering Societies Building was devoted to the presentation of seven papers by representatives of seven of the colleges in competition for a prize of $25.00 in gold offered by the New York Section. H. T. Wilhelm, Chairman of the Student Committee presided. E. B. Meyer, Chairman of the New York Section made an address of "Welcome." The balance of the afternoon program was as follows:

"The Engineer's Place in Civilization", E. C. Siddons, Rutgers; "A Six-Year Engineering Course", John Balet, Columbia; "Methods of Stage Lighting", P. H. Taylor, Stevens; Movie—"Should Men Walk Home", featuring Mabel Normand; "Railway Signaling" (illustrated), H. T. Wilhelm, Cooper Union; "Automatic Train Control", R. W. Jenkins, Newark College of Engineering and co-operating with the D. L. & W. R. R.; "The Transmission of Motion Pictures by Radio", J. I. Heller, Brooklyn Polytechnic; "Crystal Oscillators", C. Ligh, New York University.

Members of the Committee of Award were unamimous in their decision giving the prize to J. I. Heller of the Brooklyn Polytechnic Institute with honorable mention of R. W. Jenkins of the Newark College of Engineering. Attendance at the afternoon session numbered approximately 350.

At 6:30 p. m. a dinner was served at the Fraternity Club and was participated in by about 125 students and members of the Section.

In the evening, the New York Section held its regular monthly meeting, specially arranged to be of interest to students, as reported under Section Meetings in this issue. The announce-

ment of the results of the balloting for N. Y. Section officers for 1927-28 were made, as follows:

L. W. W. Morrow, Chairman; J. B. Bassett, Secretary-Treasurer; and for Executive Committee, H. C. Snook and R. R. Kime. Dr. Willis R. Whitney, Director, Research Laboratory of the G. E. Co., then delivered an address on "Your Outlook." He followed this talk, at the urgent request of the audience, with a further talk on some of his own personal research work. Both talks proved exceedingly interesting to an audience of practically 400 people.

A. I. E. E. BRANCH ORGANIZED AT DUKE UNIVERSITY

Authorization was granted by the Board of Directors on February 10, 1927, for the establishment of a Student Branch of the Institute at Duke University, Durham, North Carolina. An organization meeting was held on March 3, 1927 and the following officers were elected: Chairman, Oren Long; Vice-Chairman, O. T. Colclough; Secretary-Treasurer, W. C. Earnhardt. Plans have been made for several activities, including an Electrical Show.

Eight Branches have been organized since August 1, 1926, and the total number is now 95.

ENGINEERING EXPOSITION TO BE HELD AT LEWIS INSTITUTE

The Lewis Institute Branches of the A. I. E. E. and the Western Society of Engineers will hold an Engineering Exposition at Lewis Institute, Madison and Robey Streets, Chicago, on May 18, 19 and 20.

An extensive display of many recent developments in engineering will be arranged. The Commonwealth Edison Company will provide an exhibit and lecture portraying the principal features of its power stations and distribution system. An especially interesting demonstration of manual and machine switching will be supplied by the Illinois Bell Telephone Company.

There will be no charge for admission.

ENGINEERING SHOW AT UNIVERSITY OF SOUTHERN CALIFORNIA

The University of Southern California Branch participated in an Engineering Show which was held in the electrical engineering laboratory on March 18, 1927. Some of the electrical exhibits were radio, artificial lightning and an oscillograph. There were also exhibits in chemical engineering, physics, petroleum, and geology.

The following motion pictures were shown: Boulder Dam Project, Bureau of Power and Light (of Los Angeles) System.

The attendance was about 300.

SECTION AND BRANCH CONFERENCE AT PORTLAND

The Executive Committee and the Committee on Student Activities of District No. 9 held a joint meeting at Portland, Oregon, on February 18, 1927. It was attended by Section and Branch officers and Branch Counselors; all Sections and Branches in the District were represented. The purpose of holding such a joint Conference was to secure the greatest possible cooperation between the Sections and Branches. Vice-President Schoolfield presided.

During a discussion of joint meetings between Sections and Branches, information was presented showing that the Portland Section holds one meeting a year, presided over by officers of the Oregon Agricultural College Branch, with a program furnished by students; the Seattle Section conducts two meetings each year with the University of Washington Branch, at which Section officers preside and Section members supply the program; and the Utah Section has one meeting each year with the University of Utah Branch, with Branch officers presiding and furnishing the program.

A discussion was begun in the morning and continued in the afternoon session dealing with the best time for holding Branch Meetings, methods of interesting students in the programs, attendance, etc., representatives from all Branches contributing any information available.

The latter part of the afternoon session was devoted to a discussion of Section problems, such as dinner meetings versus non-dinner meetings, most popular subjects for meetings, printing of programs for entire season in advance, etc. Conclusions were reached that the more general subjects cause better attendance, and that programs for the year should be printed in advance.

The Student Branch representatives were guests of the Sections of the District at dinner, after which all attended the regular meeting of the Portland Section.

CARRIER CURRENT TELEPHONY

BY

J. G. Haydock, Jr.*

Enrolled Student of the A. I. E. E.

An abridgment of a paper for which the University of Pennsylvania Branch was awarded the cup offered by The Drexel Institute for the best paper presented at the Student Convention held at that institution on March 21, 1927.

In carrier current telephony, the voice controls the amplitude of a current having a frequency above the voice range.

All carrier current systems employ some method of modulation, which is the process of combining the signal current having a frequency denoted by q with a carrier current having a frequency denoted by p. The vacuum tube is the best modulating device.

If an alternating potential having component frequencies p and q is applied to the grid of a vacuum tube, the output will contain frequencies p, q, $p + q$, $p - q$, $2\,p$, and $2\,q$. A circuit of suitable characteristics will eliminate all except p, $p + q$, and $p - q$ if q is small compared with p. $p + q$ is called the upper and $p - q$, the lower sideband of p. The letter q symbolizes a single (steady-state) frequency which represents all the components of the voice. In practise, q may be any frequency from 200 to 2500 cycles per second. If the two potentials of sideband frequency and the carrier are impressed upon another tube, its output contains components of frequencies p, $2\,p + q$, q, $2\,q$, and several others. The audible ones are q and $2\,q$, and the latter is undesirable because it is introduced in detection. It is, therefore, possible to raise and lower the frequency band of a voice conversation at will, and without much distortion. The current component of frequency $2\,q$ is caused by the modulation of one sideband by the other. It is possible and desirable to eliminate a sideband when the carrier frequency is not too high in comparison with the lowest original signal frequency.

The purpose of the carrier, after modulation has been accomplished, is to provide the necessary components for the frequency subtraction process of detection. The intensity of the signal frequency output of the detector tube is directly proportional to the carrier potential and to the sideband potential applied to the detector grid. The magnitude of the detected components having twice signal frequency is proportional to the square of the sideband potential. Since these double frequency components do not appear in the original signal, they distort the detector output. Practically, the sideband amplitude may not exceed 30 per cent of the carrier amplitude when both side bands are transmitted.

To obtain fair intensity of detector output with single sideband transmission, the relative magnitude of carrier and sideband given above still applies. The carrier potential would be 77 per cent, and the carrier power about 60 per cent of the total. The transmitting amplifier would be loaded to 60 per cent of

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capacity in amplifying the carrier which is necessary, but serves no useful purpose in the transmission of intelligence. The potential of carrier frequency necessary in detection may be supplied locally, and the total capacity of the amplifier may then be used for amplifying the power in the sideband.

By means of modulation, the frequency band occupied by a telephone conversation may be shifted at will, and several simultaneous connections may be made over a single pair of wires. Transmission difficulties are multiplied, but on long distance service the carrier current system has been found economically feasible. The earliest regular carrier current channels were installed between Pittsburgh and Washington in 1917. Recently the carrier current method has made possible twelve independent channels between Los Angeles, California, and Santa Catalina Island on two single-conductor cables.

The New York-London radio telephone service employs some of the most unique applications of these principles.

After a long series of tests the Bell System selected 60,000 cycles as the best frequency for the radio service they planned. The elimination of one speech sideband of a 60,000 cycle carrier requires a filter which will pass 60,200 cycles and absorb currents having frequencies below 59,800 cycles. Such rigorous requirements can be met, but only with very complicated and expensive apparatus. At a lower frequency the attenuation of a practical filter may increase the necessary amount in the given space of 400 cycles.

Modulation is carried out at a frequency of 33,000 cycles, at which the desired filter properties can be obtained, and the carrier-frequency output of the modulator tube is eliminated by inducing in the circuit an equal carrier frequency electromotive force in phase opposition. The upper sideband which varies from 33,000 to 35,500 cycles is absorbed in a suitable filter, and the other sideband, 33,000 to 30,500 cycles, is combined in a second modulator with the 89,000 cycle output of a second oscillator. One sideband of the output of this second modulator lies between 56,000 and 59,000 cycles. The carrier and the other sideband, which has a frequency of about 120,000 cycles, are eliminated by usual methods. The filter must eliminate frequencies above about 80,000 and below about 40,000 cycles effectively. The single remaining band 56,000 to 59,000 cycles, is amplified through several stages, the output of the last being about 100 kilowatts. The energy in the carriers generated throughout the system is the output of five watt tubes and, while this is wasted, the loss is negligible. In the receiver is a carefully adjusted oscillator which brings out the original speech frequency currents.

The carrier wave telephone application is of greater economic importance. The load factor on existing lines is increased, and the added costs of new lines are avoided.

The extension of vocal communication to many European countries by radio and wire interconnections will undoubtedly influence future economic and political relations.

Reference: R. A. Heising, "The Production of Single Side-Bands for Trans-Altantic Radio Telephony," *Proc.* Institute of Radio Engineers, June 1925.

BRANCH MEETINGS

Alabama Polytechnic Institute

Work in the Various Branches of the Engineering Field, by Mr. Crampton, Western Electric Co. March 17. Attendance 60.

Development in Electrical Dredging During 1926, by G. L. Kenny;

The A. I. E. E. Hike of March, by R. C. Malbourg;

Summer Work with the Southern Bell Telephone & Telegraph Co., by W. L. Garlington, and C. N. Worthington. March 24. Attendance 54.

Armour Institute of Technology

Making Light of the Mystery, by W. A. Durgin, Director of Public Relations, Commonwealth Edison Co. A working model of a modern power plant and distribution system was exhibited. Joint meeting. March 3. Attendance 350.

Business Meeting. March 17. Attendance 30.

Motion pictures, entitled "Speeding Up to the Deep-Sea Cables," and "A Telephone Call," were shown. April 7. Attendance 60.

University of California

Initiation and Banquet. Talks were given by Major Pinger, Lieut. Col. Kelly, Dean C. F. Cory, Prof. Weeks and Chairman F. H. McCune. March 3. Attendance 90.

Carnegie Institute of Technology

The Machine Switching Telephone Exchange, by H. E. Chisholm, Bell Telephone Co. of Western Pennsylvania. Illustrated with slides. The following officers were elected: Chairman, R. A. Giles; Vice Chairman, D. L. Putt; Secretary, J. R. Britton; Treasurer, C. E. Eckels. April 6. Attendance 30.

Case School of Applied Science

Carbon—Its Manufacture and Uses, by P. D. Manbeck, Development Engineer, National Carbon Co., Inc. Illustrated with motion pictures. March 12. Attendance 52.

Control of Street Lighting, by A. J. Kres, student, and

Faraday, by M. Hirschfield, student. The following officers were elected: Chairman, G. J. Currie; Vice-Chairman, M. S. Schonvizner; Secretary, R. C. Taylor; Treasurer, R. M. Lawall. March 19. Attendance 54.

The Life and Works of James Clerk Maxwell, by R. W. Osterholm, student;

Discussion of Thesis, by L. C. Bond, student;

Lord Kelvin and His Contributions to Electrical Engineering, by S. E. Abell, student. March 29. Attendance 55.

The Selection of Telephone Engineering Personnel, by W. J. Eastman, Director of Instruction, The Ohio Bell Telephone Co. Motion pictures of the telephone industry. Supper Meeting. March 31. Attendance 43.

Catholic University of America

The Magic of Communication, by John Mills. An address was given by a representative from the American Tel. & Tel. Co., telling the opportunities for employment in the company. March 15. Attendance 48.

Colorado State Agricultural College

Business Meeting. March 28. Attendance 15.

University of Colorado

The Conference on Student Activities of the Sixth Geographical District Held at the University of Colorado, by Joe A. Setter, student. Motion pictures, entitled "Laying the World's Fastest Submarine Cable," "The Magic of Communication," and "Yours to Command," were shown. March 9. Attendance 50.

History and Development of Radio, by W. H. Hyslop, Professor of Physics, University of Denver, Talk and demonstration. Motion picture, entitled "The Wizardry of Wireless," was also shown. March 30. Attendance 90.

Cooper Union

How to Become a Successful Engineer, by Farley Osgood, Past President, A. I. E. E. Following the talk a motion picture, showing points of scenic interest in Canada, was shown: also one on the smelting and refining of copper at the Baltimore Smelting and Refining Works. Joint meeting with A. S. M. E. and A. S. C. E. March 26. Attendance 125.

University of Denver

Business Meeting. April 1. Attendance 16.

Iowa State College

Engineering for Manufacture, by E. C. Higgins, Personnel Assistant, Western Electric Co., Chicago. March 2. Attendance 40.

Personnel Management, by E. C. Higgins, and

Personnel System of Iowa State College, by M. R. Good, Assistant to Dean of Engineering. March 2. Attendance 33.

Kansas State College

Automobile Headlight Problems, by Prof. R. G. Kloeffler. March 7. Attendance 55.

Opportunities for Engineering Graduates with the General Electric Company, by L. H. Means, Ass't. General Foreman, Testing Dept., General Elec. Co. March 21. Attendance 150.

Mr. A. M. Young, Chairman of the Branch, gave a report of the Conference on Student Activities which he attended in connection with the Kansas City Regional Meeting, March 16. April 4. Attendance 85.

Steam Turbines, by H. W. Cross, General Electric Co. April 7. Attendance 80.

University of Kansas

Hundred Percent Trunking in Telephone Work, by George Herold, student, and

The Biography of George Westinghouse, by Eugene McDonald, student. Discussion of the stunts which the Electrical Department is to put on during the Engineering Exposition to be held April 22 and 23. April 6. Attendance 52.

University of Kentucky

Business Meeting. The following officers were elected: Chairman, R. W. Spicer; Secretary, C. D. McClanahan. October 28. Attendance 29.

Inspection of Dix River Dam under the supervision of Prof. E. A. Bureau. December 8. Attendance 33.

Interference in Telephone Circuits Due to Power Lines, by Prof. E. A. Bureau. March 1. Attendance 29.

Lewis Institute

Displays and Advertising, by Mr. Wolfing, Commonwealth Edison Co., and

Advertising and My Experience in Connection with Shows, by Mr. Fenschholt. Reports from all committees in connection with the Electrical Show to be held May 18-19-20. March 23. Attendance 30.

Louisiana State University

Transformers and Super Power Systems, by H. O. Stephens, Transformer Dept., General Electric Co. Supplemented with slides. Joint meeting with A. S. M. E. March 23. Attendance 106.

Marquette University

Prof. J. F. H. Douglas, Counselor of the Branch, gave an account of his trip to New York where he attended the Winter Convention, A. I. E. E., to present his paper *Transverse Reaction in Synchronous Machines.* He discussed the program of the convention, telling of the work being carried on by the Institute. The following officers were elected: Chairman, J. R. Adriansen; Vice-Chairman, Philip Neumann; Secretary, H. J. Lavigne; Treasurer, Bernerd Pratte. March 10. Attendance 38.

Massachusetts Institute of Technology

The Edgar Station of the Edison Company, by I. E. Moultrop, Chief Engineer, Edison Elec. Illuminating Co. Illustrated with slides. March 24. Attendance 35.

University of Michigan

Radio Frequency Measurements, by R. R. Swain. Illustrated by the use of a high-frequency oscillator and a short transmission line. March 21. Attendance 75.

Milwaukee School of Engineering

Various Industrial Engineering Problems, by S. A. Moore, Electrical Engineer, Hole-Proof Hosiery Company. April 7. Attendance 10.

University of Minnesota

Gas Electric Buses, by C. E. Swanson. The Minnesota Branch is sponsoring an Electrical Show which will be given on April 21 and 22. April 6. Attendance 20.

Missouri School of Mines and Metallurgy

Professor Lovett gave a talk on the Regional Meeting and Conference on Student Activities of the A. I. E. E. in Kansas City. March 1. Attendance 12.

Montana State College

Report on Conference of Section and Branch Officers and Branch Counselors of the 9th District, A. I. E. E., held at Portland, Oregon, on February 18, 1927, by W. E. Pakala, President. February 24. Attendance 161.

The Three Element Vacuum Tube and Modern Radio, by H. T. Plumb, General Electric Co. Banquet. March 8. Attendance 61.

The Meaning of Education, by H. T. Plumb, March 8. Attendance 211.

A New Electrical Rectifier, by Paul Clark, and

Directional Control of Light for Street Illumination, by Melvin Barbour. March 24. Attendance 141.

Newark College of Engineering

The Transmission of Pictures by Wire, by G. S. Anderson, New York Telephone Co. Illustrated with slides. March 16. Attendance 21.

College of the City of New York

Motion pictures, entitled "The King of the Rails," and "The Story of Compressed Air," were shown. April 7. Attendance 62.

Business Meeting. The Student Convention trips and papers were discussed by the students who attended the convention. April 14. Attendance 13.

University of North Carolina

Oil Switches and Circuit Breakers, by Mr. Wheeler. February 24. Attendance 20.

Illumination, by Prof. J. E. Lear. March 10. Attendance 22.

Business Meeting. March 31. Attendance 26.

University of North Dakota

The Ideal Layout of Substations and Feeders in the Serving of a Medium-Voltage A. C. Network, by Walter Kloster. Mr. Eielson gave a discussion of the purposes and results of the District Conference on Student Activities at Boulder, Colorado, on February 26. Discussion of plans for Engineer's Day to be held in May. March 14. Attendance 15.

Northeastern University

Cable Testing, by H. C. Hamilton, Assistant Supt. of the Standardizing and Testing Dept. of the Edison Electric Illuminating Co. Illustrated by stereoptican slides. March 22. Attendance 90.

Notre Dame

Psychology and Its Relation to Engineering, by Mr. Greene;

Poetry, by Larry Wingerter, and

Rectification, by Mr. C. P. Hafel, Instructor in Electrical Engineering. March 14. Attendance 30.

Ohio University

Motion picture, entitled, "Power," was shown, also a film furnished by the Westinghouse Company, showing some of their factories. March 16. Attendance 25.

Ohio Northern University

Business Meeting. March 17. Attendance 17.

Business Meeting. Nomination of officers for next year. March 31. Attendance 25.

Business Meeting. The following officers were elected: Chairman, John Simmons; Vice-Chairman, N. D. Ackley; Secretary, Verl Jenkins; Treasurer, L. R. Althaus. April 7. Attendance 26.

Oklahoma A. & M. College

Mr. H. M. Horton, Chairman of the Branch, gave a report on the Conference on Student Activities held at Kansas City on March 16. The following motion pictures were shown: "The Electric Giant," "Sugar Trail," "Light of a Race" and "Thomas Edison." Officers were elected as follows: Chairman, Benny Fonts; Vice Chairman, Charles Wyatt; and Secretary, Jerry Robertson. April 6. Attendance 25.

Oregon Agricultural College

Business Meeting. Discussion of means of obtaining greater interest in meetings. March 15. Attendance 11.

Pennsylvania State College

Short sketches of four great pioneers of electrical engineers were given by students: "George Westinghouse," by J. A. High; "B. G. Lamme," by S. F. Schmidhamer; "C. P. Steinmetz," by C. L. Stotler, and "Thomas A. Edison," by R. W. Zehner. March 30. Attendance 32.

University of Pennsylvania

Business Meeting. Discussion of Student Convention to be held at Drexel Institute, March 21. March 4. Attendance 28.

University of Pittsburgh

Telephone Communication, by E. E. Meurer, student. March 4. Attendance 27.

Testing of Aluminum, by R. L. Templeton, Materials Testing Engineer of the Aluminum Company of America. March 11. Attendance 150.

Voltage Regulators, by Avner Abulafia, student, and

Nela Park and the Operations Carried on at that Place, by Hamilton Brooks, student. March 18. Attendance 27.

The Use of Models in the Construction of Electric Locomotives, by G. W. Connell, student, and

Automatic Train Control, by Charles Caveny, student. March 25. Attendance 24.

Princeton University

The Corona Effect, by H. C. Riggs, student. April 11. Attendance 6.

Purdue University

Turbines, by H. W. Cross, Turbine Expert, General Electric Co. Illustrated with slides. Joint meeting with A. S. M. E. March 29. Attendance 105.

Rensselaer Polytechnic Institute

Low Voltage Rectification, by Dr. M. A. Hunter, Dept. of Physics and Electrical Engineering. The speaker introduced a number of graduate students: Wendell F. Hess gave demonstration of the characteristics of the various types; K. E. Faiver spoke of life tests of the solid rectifiers, and G. R. Town and L. B. Hochgraf showed a number of oscillograms, illustrating the rectification characteristics of the different types. March 22. Attendance 115.

Business Meeting. Discussion of plans for the Student Convention to be held at Pittsfield in connection with the Regional Meeting in May. April 1. Attendance 30.

Rhode Island State College

Mr. James E. Ralston, student, gave an interesting and exhaustive survey of the developments in turbo-generators. February 2. Attendance 21.

Radio Photography, by C. F. Easterbrooks, student. March 2. Attendance 24.

Taking Power from Sea Water, by G. A. Eddy, Branch Chairman. March 9. Attendance 15.

Copper Mining in Michigan, by Prof. William Anderson, Counselor. Illustrated. March 30. Attendance 16.

Rutgers University

Interconnections, by Mr. Scherbo, student;

Installation, Operation and Care of Direct Current Machines, by Mr. Kieb, student, and

The Conowingo Power Plant, by E. C. Siddons, President of the Branch. March 16. Attendance 18.

University of Santa Clara

Transmission of Photographs over Telephone Lines, by W. E. Williams, Pacific Tel. & Tel. Co. Illustrated. March 22. Attendance 63.

South Dakota State School of Mines

Business Meeting. Prof. J. O. Kammerman gave a detailed report on the Conference on Student Activities held at Boulder, Colorado, on February 26. Mr. D. A. White was elected Chairman for the next school year. April 18. Attendance 20.

University of Southern California

Business Meeting. Nomination of officers for second semester. January 7. Attendance 47.

Employment and Practical Engineering, by L. F. Hunt, Gilbert E. Laue and C. H. Sturm. February 24. Attendance 31.

Engineering Show. Several exhibits and the following motion pictures: "Boulder Dam Project;" and "Los Angeles Bureau of Light and Power." March 18. Attendance 300.

University of South Dakota

Chairman Stanley Boegler gave a report on the Conference on Student Activities at Boulder, Colorado, on February 26. March 16. Attendance 7.

Vacuum Switches, by Mr. Vallin. Mr. Muchow talked upon possible undertakings for Engineer's Day. March 30. Attendance 6.

Swarthmore College

Mr. O. H. Ammon, Bridge Engineer for the Port of New York Authority, described the plans for the new Fort Lee Bridge to be built across the Hudson River. Pictures of the bridge. March 14. Attendance 25.

Syracuse University

Hydroelectric Development in Russia, by V. A. Hilarov. December 15. Attendance 24.

Electrification of Chicago, Milwaukee and St. Paul Railroad, by H. C. Robb and O. B. Hudson. January 5. Attendance 22.

Power Development in Alaska and Its Possibilities, by G. F. Kem. January 12. Attendance 24.

Power Transmission in Southern California, by A. E. Krawcek. February 17. Attendance 23.

Hydraulic Power Development in Africa, by R. D. McNutt. February 24. Attendance 22.

Developments of Cohoes Power Company of Albany, by F. P. McNally. March 3. Attendance 24.

Texas A. & M. College

Recent Developments of Electrical Machinery, by John Liston, Technical Writer, Publication Bureau, General Electric Co. March 11. Attendance 90.

University of Texas

Homopolar Machine, by B. D. Bedford, student. Chairman A. L. Mayfield reported on the A. I. E. E. Regional Meeting and Conference on Student Activities at Kansas City. Spring term officers: President, A. L. Mayfield; Vice-President, H. H. Chapman; Secretary-Treasurer, L. L. Autes; Corresponding Secretary, G. E. Schade. March 30. Attendance 16.

Virginia Military Institute

Power Development from Tropical Water, by L. S. Griffith;

Electrical Developments of 1926, by M. Rubin;

Developing a High-Voltage Network in Germany, by O. V. Sessoms, and

The Electrification of the Staten Island Railroad, by C. U. Boykin. February 19. Attendance 22.

Motion picture, entitled "Single Ridge," was shown. February 21. Attendance 51.

Motion picture, entitled "The Benefactor," was shown. March 1. Attendance 52.

Manufacturing by Electric Heat, by B. E. Nelson;

Illumination of Railroad Classification Yards, by E. W. Kriete;

Steam Turbines, by D. N. Higgins, and

The Engineer, by J. F. Adams. March 21. Attendance 50.

Washington and Lee University

Arc-Welding, by C. L. Eigelbach. March 14. Attendance 10.

Motion picture, entitled "King of the Rails," was shown. The following officers were elected: Chairman, R. E. Kepler; Vice-Chairman, J. B. Copper; Secretary-Treasurer, Bernard Yoepp. March 25. Attendance 8.

Motion picture, entitled "Thomas A. Edison," was shown. April 8. Attendance 9.

State College of Washington

Electric Propulsion of Ships, by Prof. R. D. Sloan, Counselor. February 9. Attendance 29.

Engineer's Show, by Past President Stewart White. Plans were discussed for the various Electrical Stunts for the Show. March 23. Attendance 18.

West Virginia University

The Automatic Safety Control for Railroads, by E. W. Conway;

Installation of a Coal Belt-Conveyor System, by S. C. Hill;

A Remodeled Calendar, by P. E. Davis;

What is an Engineering Education, by S. J. Donley;

Automatic Switches, by J. R. Cook;

New Gifts of Science, by G. B. Pyles; and

Progress in Fuels Engineering, by L. T. Knight. March 11. Attendance 38.

Rapid Transit in Large Cities, by C. M. Borro;

A Personal Inventory, by Albert Izzo;

Beam Transmitters in Wireless, by M. S. Diaz;

Transportation to the Moon, by W. T. Myers;

French Construction of Airships, by R. O. Pletcher;

Electrical Navigation, by F. M. Farry;

City Transit Service, by C. L. Parks;

Television, by H. H. Hunter;

Engineering in the United States, by J. P. Paine; and

Washing Pittsburg's Cars, by A. L. Lindley. March 18. Attendance 38.

Developments in the Electrical Field in 1926, by A. L. P. Schmeichel;

Resonant Control of Street Lighting, by W. E. Vellines;

Public Speaking and Engineering, by Albert Izzo; and

Oxy-Acetylene Welding, by G. E. Phillips. March 25. Attendance 38.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is adminstered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES MARCH 1-31, 1927

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Ancient Egyptian Metallurgy.

By Major H. Garland and C. O. Bannister. Lond., Charles Griffin & Co., 1927. 214 pp., illus., port., 8 x 5 in., cloth. 12 s 6d.

Major Garland was for many years Superintendent of Laboratories at the "Citadel," Cairo, during which time he had unusual opportunities to collect and examine ancient specimens of metals.

Unfortunately, his death prevented him from publishing an account of his investigations. His notes and memoranda have, however, been arranged for publication by Mr. Bannister. They treat of the sources from which ancient Egypt obtained metals, of its bronze industry, of the iron age in Egypt and of ancient Egyptian tools. A chapter is devoted to Major Garland's metallographic investigations of antique metals and his conclusions from them.

Der Bau Langer Tiefliegender Gebirgstunnel.

By C. Andreae. Berlin, Julius Springer, 1926. 151 pp., illus., diagrs., 10 x 7 in., paper. 13,20 r. m.

The purpose of this work is to make easily available the technical and scientific results obtained during the construction of the great Alpine tunnels. The author makes no attempt at a complete treatise upon tunneling but confines himself to matters pertaining specially to long, deep tunnels. The topics discussed include drilling, removal of rock, geological conditions, ventilation, cooling, systems of tunneling, methods of construction, lining, sanitation and costs.

Catalysis in Theory and Practise.

By Eric K. Rideal and Hugh S. Taylor. Lond. & N. Y., Macmillan Co., 1926. 516 pp., 9 x 6 in., cloth. $6.00.

First published in 1918, this work now appears in completely revised form, with several added chapters. It aims to present a critical survey of the catalytic field from the viewpoint of theory. It will be useful to those who wish an exposition of fundamental principles, illustrated by suitable data from the numerous applications in industry and science.

Economic Basis of Fair Wages.

By Jacob D. Cox, Jr., N. Y., Ronald Press Co., 1926. 139 pp., diagrs., 9 x 6 in., cloth. $3.50.

A brief discussion of the economic theory of wages, of the factors that determine money wages, of the laws of prices and of real wages and of the question of fair wages. The object is to present the fundamentals upon which wages must be based, in order to be fair to both worker and employer.

Die Eigenschaften Elektrotechnischer Isoliermaterialien in Graphischen Darstellungen.

By U. Retzow. Berlin, Julius Springer, 1927. 250 pp., graphs, 9 x 6 in., boards. 24.-r. m.

The contents of this book are unusual. The first half consists of three hundred and thirty graphic charts which show the electrical, physical and mechanical properties of the insulative materials used industrially. The second half gives an exhausting bibliography on insulating materials, containing some three thousand references.

Except for a brief introduction, the author has provided no text. The source of each chart is clearly indicated and references are also given to the other publications upon the subject. The book brings together a great amount of scattered information and should prove of great assistance to all who have to do with the design and construction of electrical apparatus.

Der Eisenbau.

By Luigi Vianello. 3rd edition. Mün. u. Ber., R. Oldenbourg, 1927. 617 pp., diagrs., tables, 9 x 6 in., paper. 30.-r. m.

A reference book for structural engineers which aims to present in one volume the practical and theoretical data that are usually required. The text is brief, yet clear, and the book is a convenient handbook for the designer of bridges and steel buildings.

Factory Management.

By Paul M. Atkins. N. Y., Prentice-Hall, 1926. 386 pp., illus., forms, 9 x 6 in., cloth. $5.00.

An introduction to the study of manufacturing administration, intended for those who have had a general course in business administration. The problem is approached from a practical point of view, and the control of production is emphasized as a major function of business administration. Such matters as materials, equipment, plant layout, standards, scheduling, tools, inspection and storing are discussed and good practise illustrated.

Der Flotations-Prozess.

By C. Bruchhold. Berlin, Julius Springer, 1927. 288 pp., illus., diagrs., 9 x 6 in., cloth. 27.-r. m.

Intended as a handbook of flotation for those operating flotation plants. The author has therefore confined himself to recent ideas and to a full account of the methods in use today, omitting the older processes, which have only historic interest. The book contains much information upon methods, machinery and operation, brought together in convenient form.

Geology of South Africa.

By Alex. L. Du Toit. Edinburgh, Oliver & Boyd, 1926. 463 pp., illus., map, 9 x 6 in., cloth. 28s.

A text-book upon the geology of the African continent south of the Zambesi River which gives a systematic account of present knowledge. In addition to the descriptions of the various systems represented in that area the book contains chapters upon primitive man in South Africa, upon its soils and upon its economic geology. The book contains many bibliographic references, photographs and a colored geological map based upon official surveys. The author is geologist to the Union Irrigation Department.

Die Grundlagen der Warmeubertragung.

By Friedrich Merkel. Dresden & Leipzig, Theodor Steinkopff, 1927. (Wärmelehre und Wärmewirtschaft, bd. 4) 234 pp., diagrs., tables, 9 x 6 in., paper. 13,50 r. m.

This monograph brings together the existing theoretical and experimental investigations of heat transmission in connected form, with special emphasis upon their practical applications.

The first of the five sections of the book discusses the physical laws that govern conduction in solids, especially in plates and

cylinders. Section two treats of heat transmission by conduction and convection, including the theory of the action of the combined methods and the results of experimental investigations. This section is much the largest in the book.

Section three is devoted to radiation, and section four to heat transfer through walls. Section five contains such data as the specific gravity, specific heat and conductivity of the more important solids, liquids and gases.

HANDBOOK OF CHEMISTRY AND PHYSICS. 11th Edition.

By Charles D. Hodgman and Norbert A. Lange. Cleveland, Chemical Rubber Publishing Co., 1926. 1011 pp., tables, 7 x 5 in., fabrikoid. $5.00.

Recent developments have brought physics and chemistry into such intimate relations that many workers in each science constantly need constants and formulas from the other. To these this handbook will be convenient, for it presents a large amount of information in both fields, collected from authoritative sources and systematically tabulated and arranged for quick reference.

This latest edition has been revised in the light of recent advances and enlarged by the addition of considerable new material.

HANDBUCH DER STEINKONSTRUKTIONEN.

By Otto Frick. Berlin, Willy Geissler Verlag, 1927. 500 pp., illus., diagrs., tables, 11 x 8 in., paper. 18.-r. m.

A comprehensive text upon masonry construction, intended especially to cover practical questions and serve as a handbook to builders. The work begins with a discussion of the physical properties of masonry materials. Foundations and waterproofing are then considered, after which brick and stone buildings are considered in detail. The final sections of the book discuss concrete and reinforced concrete structures.

JOURNAL OF THE ROYAL TECHNICAL COLLEGE, No. 3, Dec. 1926. Glasgow, 1926. 180 pp., 10 x 7 in., paper. 10s 6d.

This number of the Journal describes some of the researches carried out at the College. Those of special interest to engineers include studies of the overstraining of steel by tension, a simple method of comparing heat insulating materials, the passage of electricity through dilute solutions, the overheating of mild steel, and some physical properties of duralumin.

KINETIC THEORY OF GASES.

By Leonard B. Loeb. N. Y., McGraw-Hill Book Co., 1927. 555 pp., 9 x 6 in., cloth. $5.50.

Professor Loeb has endeavored to fill the need for a textbook upon modern kinetic theory which is not too abstruse for the average college student and which will serve as preparation for more advanced writings. He begins with a concise presentation of the various concepts and classical derivations of the kinetic theory for third-year college students and then proceeds on toward the needs of advanced students and investigators for a convenient, more elaborate account of the phenomena in question.

LAW OF CHEMICAL PATENTS.

By Edward Thomas. N. Y., D. Van Nostrand Co., 1927. 420 pp., 9 x 6 in., cloth. $6.00.

Mr. Thomas' book is intended for attorneys, inventors and chemists interested in the validity or scope of a patent or in the status of an invention, who wish some guidance through the technicalities of the patent law. He discusses the nature of a patent, disclosure, the nature and date of the invention, the nature of patentable processes and manufactures, anticipations, claims, infringements, amendments, double patenting, assignments, rival claimants and patent suits. Under each heading he gives a short introduction and quotations from many court decisions which illustrate the questions involved and guide the reader to cases in which the principles involved are discussed.

MAKERS OF SCIENCE; Electricity and Magnetism.

By D. M. Turner. Lond. & N. Y., Oxford University Press, 1927. 184 pp., illus., ports., diagrs., 8 x 5 in., cloth. $2.50.

Mr. Turner describes the main development of electrical science up to the beginning of the twentieth century in this little volume, which is attractively illustrated with portraits of famous electricians and pictures of early experiments. The book is intended for young students and general readers. It gives a clear, readable account of the growth of the science and fills a gap in the literature of the subject.

MANUFACTURE OF PULP AND PAPER. V. 3. 2nd Edition.

By Joint Executive Committee of the Vocational Education Committees of the Pulp and Paper Industry. N. Y., McGraw-Hill Book Co., 1927, various paging, illus., tables, 9 x 6 in., cloth. $5.00.

A comprehensive work upon the manufacture of wood pulp, prepared by a number of specialists for the Canadian Pulp and Paper Association and the Technical Association of the Pulp and Paper Industry. The book is intended primarily for use as part of a course of vocational study of the paper industry, but is in addition the most satisfactory account of its subject now available in English.

This edition includes accounts of developments during the past six years, such as bark presses, automatic grinders, continuous causticizers, pulp washing and the recovery of fiber from effluents.

MARVELS OF MODERN MECHANICS.

By Harold T. Wilkins. N. Y., E. P. Dutton & Co., 1927. 280 pp., illus., 9 x 6 in., cloth. $3.00.

Contents: Conquest of the atom. Strong rooms of the sea-bed. Probing the sun's secrets. Far North and the seal hunters. Wonders of wires and wireless. Marvels of modern excavation. Charting unknown seas to-day. Human flashlights underground and a contrast. Making the earth work. Cable-ship on the high seas. Safer airways of to-day. Scenic art of the modern theatre. Revolution on the ocean.

A popular account of recent discoveries and inventions, intended for the general reader. Calls attention to many recent advances in engineering, physics and chemistry.

MATHEMATICAL ANALYSIS FOR ENGINEERS.

By Miles A. Keasey. Phila., The Author, 1926. 193 pp., 9 x 6 in., leatherette. $2.75.

An extension of mathematics beyond the treatment given in texts on algebra, geometry and trigonometry, intended for students of engineering and restricted to those principles of coordinate geometry and calculus which apply most directly to engineering practise. The text, however, is not a "practical mathematics," but a direct treatment of mathematical principles. It is intended for such courses as those given at the Drexel Institute Evening School.

MATTER AND GRAVITY IN NEWTON'S PHYSICAL PHILOSOPHY.

By A. J. Snow. Lond. & N. Y., Oxford University Press, 1926. 256 pp., 8 x 5 in., cloth. $2.50. (Gift of American Branch.)

Contents: The Atomic revival. Newtonian Atomism. Newton's doctrine of gravity. Newton's metaphysical doctrine of gravity. Role of mathematics and hypothesis in Newton's physics. Bibliography.

This essay, which covers a most important and critical period of natural science, is especially timely at present, when the adequacy of Newtonian mechanics is being questioned. It traces the development of the atomic theory and attempts to present Newton's conception of the nature and function of atoms. The author presents a study of some of the fundamental concepts of Newton's physical philosophy and of the influence upon Newton's views of his predecessors and contemporaries.

MODERNE GRUNDBAUTECHNIK, t. 2; Theorie der Tiefschochtgründungen mit der Grundkörpermaschine.

By Ottokar Stern. Berlin, Wilhelm Ernst & Sohn, 1927. 56 pp., illus., diagrs., 8 x 5 in., paper. 2,70 r. m.

This pamphlet discusses, from a theoretical and a practical point of view, the application of the "compressol" system to deep foundations, foundations under water, etc. The author discusses the dynamics and statics of the problem and gives examples of special applications.

NON-TECHNICAL CHATS ON IRON AND STEEL.

By La Verne W. Spring. New edition. N. Y., Frederick A. Stokes Co., 1927. 465 pp., illus., tables, 9 x 6 in., cloth. $4.00.

A popular, readable account of the iron industry, describing the metallurgical and mechanical processes of the blast-furnace, steel works, foundry and rolling-mill, and accompanying the text by numerous well selected photographs. This edition has been revised and enlarged to cover recent changes.

PROPERTIES AND TESTING OF MAGNETIC MATERIALS.

By Thomas Spooner. N. Y., McGraw-Hill Book Co., 1927. 385 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

In this book the principal objects are to give a reasonably complete summary of the magnetic properties of commercial ferromagnetic materials, to describe the useful methods of testing for commercial inspection and scientific investigation, and to examine critically the accuracy and limitations of these methods. The work is intended for those who wish definite information for use in the solution of some specific magnetic problem, and therefore does not discuss matters of theory or topics that have no engineering significance.

The choice of data and information is based upon the lengthy experience of the author with the problems that arise in the design and construction of electrical apparatus.

PROPERTIES OF INORGANIC SUBSTANCES. 2nd Edition, enlarged.

By Wilhelm Segerblom. N. Y., Chemical Catalog Co., 1927. 226 pp., 9 x 6 in., cloth. $6.00.

While this book will have a variety of uses, its special purpose is to assist the analyst by giving him, in convenient form, a list of properties that will enable him to corroborate the results of qualitative analyses. The data are arranged in the six regular groups of bases and in additional sections covering acids, non-metals and rare metals. An extensive index is provided. The properties include color, luster, crystalline form, deliquescence, stability, melting-point, solubility and similar characteristics.

RADIO ENCYCLOPEDIA.

Compiled by Sidney Gernsback. N. Y., Sidney Gernsback, 1927. 168 pp., illus., diagrs., 12 x 9 in., leatherette. $2.00.

A convenient compilation of radio terms and data, arranged alphabetically and accompanied by a classified index. Nearly two thousand words and terms are defined and many diagrams of circuits and apparatus are included. The book is a handy work of reference.

STABILITY AND SEAWORTHINESS OF SHIPS.

By T. B. Abell. Liverpool, University of Liverpool Press: Lond., Hodder & Stoughton, 1926. 297 pp., diagrs., tables, 9 x 6 in., cloth. 18s.

Written, says the preface, to be "of service to all those who have to prepare a ship at its loading port for its prospective voyage and who have to navigate it and handle it during its passage to its port of discharge." It discusses the fundamentals of a ship's stability and considers those problems affecting stability and seaworthiness which the shipmaster may be called upon to deal with or consider in his ordinary routine.

DIE STADTEHEIZUNG; Bericht über die vom Verein Deutscher Heizungs-Ingenieure E. V. Einberufene Tagung, Oct. 1925, Berlin. Mün. u. Ber., R. Oldenbourg, 1927. 209 pp., 10 x 7 in., paper. 8.-r. m.

The report of a conference upon district heating held in Berlin in October, 1925, under the auspices of the Society of German Heating Engineers. The conference was attended by many heating engineers, municipal authorities, power producers and manufacturers, and the discussions are a valuable record of the development of district heating in Germany, in all its phases.

STATISTIK DER ELEKTRIZITATSWERKE UND DER ELEKTRISCHEN BAHNEN OSTERREICHS.

By Elektrotechnischen Verein in Wien. Wien, 1926. 214 pp., 12 x 9 in., boards. Price not stated.

A useful statistical survey of the electric power industry in Austria, complete to the end of 1926. The first section gives the usual items of ownership, situation and equipment for all power plants exceeding 20 kw. capacity. A second tabulation furnishes details of the prime movers of all plants surpassing 500 kw., and a third the statistics of electric railways. The work is issued by the Vienna Society of Electrical Engineers and is the first to appear since 1920.

TABLES OF PHYSICAL AND CHEMICAL CONSTANTS AND SOME MATHEMATICAL FUNCTIONS.

By G. W. C. Kaye and T. H. Laby. 5th edition. N. Y., Longmans, Green & Co., 1926. 161 pp., tables, 10 x 7 in., cloth. $4.75.

A volume of convenient size and moderate price, which contains the physical and chemical constants most frequently wanted by students and laboratory workers. References to original sources and important books and papers are given in many cases. The edition has been carefully brought up to date.

TASCHENKOMMENTAR DES PATENTGESETZES.

By Ludwig Ebermayer. Berlin, Otto Liebmann, 1926. 222 pp., 7 x 5 in., boards. 5.-r. m.

Contains the German patent and trade-mark laws, with a commentary by Dr. Ebermayer which elucidates the various provisions and contains much useful advice to patent attorneys, patentees and inventors.

TECHNISCHE SCHWINGUNGSLEHRE, 1; Allgemeine Schwingungsgleichungen.

By L. Zipperer. Ber. u. Lpz., Walter de Gruyter & Co., 1927. 111 pp., 6 x 4 in., cloth. 1,50 r. m.

The first of two small volumes upon vibration in machinery. It is a concise exposition of the general equations governing vibrations in prime movers and other machines. The author derives these equations, applies them to the determination of the vibration periods in simple systems and presents a collection of equations for various cases.

THEORIE MATHEMATIQUE DE L'ELECTRICITE; pt. 1, Introduction aux Equations de Maxwell.

By Th. De. Donder. Paris, Gauthier-Villars & Cie., 1925. 198 pp., 11 x 9 in., paper. 45 fr. (Gift of Author).

This portion of this treatise upon the mathematical theory of electricity is concerned only with electricity itself. Matter plays no role except to support or connect the two electric fluids in a state of equilibrium or motion. Electrons are not mentioned. Professor De Donder's aim has been to show how Maxwell's equations may be obtained with the greatest generality, by a simple, logical method.

THERMODYNAMICS.

By. J. E. Emswiler. 2nd edition. N. Y., McGraw-Hill Book Co., 1927. 296 pp., diagrs., tables, 9 x 6 in., cloth. $3.00.

Professor Emsweiler's textbook differs from others in its arrangement. Instead of following the usual order, he first discusses steam, then successively vapor refrigeration, permanent gases, mixtures and air heat engines; coming finally to the abstract phases of the subject, the laws of thermodynamics and the kinetic theory of gases. This arrangement, he believes, overcomes many of the difficulties usually encountered by students.

The new edition has been revised in the light of use of it as a text-book and extended to cover important applications of the principles of thermodynamics which have occurred in recent years.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS. 1926-27.

N. Y., Thomas Publ. Co. 467 8th Ave. 1926. Various paging, 12 x 10 in., cloth. $15.00.

No changes have been made in the plan or arrangement of this seventeenth edition, but the work has been revised and corrected throughout. It enables the buyer to ascertain quickly the names and addresses of sources for any desired article or the maker of any desired brand of goods. In addition, it provides lists of banks, boards of trade and other commercial organizations, exporters and importers, shipping lines and forwarding agents. The directory is thoroughly indexed. It will prove a great convenience to purchasing agents.

TRANSFORMATOREN.

By Fr. Sallinger. Ber. u. Lpz., Walter de Gruyter & Co., 1927. 113 pp., illus., diagrs., 6 x 4 in., cloth. 1,50 r. m.

A concise account of the theory, construction and testing of transformers, intended as an elementary textbook and a handy pocket reference book.

WARMESTRAHLUNG TECHNISCHER OBERFLACHEN BEI GEWOHNLICHER TEMPERATUR.

By Ernst Schmidt. Mün. u. Ber., R. Oldenbourg, 1927. (Beihefte zum Gesundheits-Ingenieur, Reihe 1, heft 20). 23 pp., diagrs., tables, 12 x 9 in., paper. 3,60 mk.

An investigation of radiation from structural materials heated to temperatures between 70° and 95° F., special attention being paid to the effect of surface conditions. The materials tested included rough and polished brass; tinned, galvanized and nickel-plated iron; polished and oxidized copper; rough and polished aluminium; rough iron and steel; painted and varnished surfaces; wood, rubber, brick, glass, roofing paper, marble, etc. A brief review of the laws of radiation, so far as they have technical importance, is also given.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

A PERMANENT POSITION in South America is open for an energetic graduate civil engineer who speaks Spanish and is qualified to successfully sell and promote materials entering into modern street and road construction. Remuneration commensurate with ability. Submit complete statement of experience and training and a recent photograph. Applications will be treated with strict confidence. X-2353-C-S.

PROFESSOR of electrical engineering, to teach classes in drawing and other subjects of general engineering nature, and electrical engineering. Desire man of agreeable personality and initiative, with some experience in teaching and practise. Apply by letter. Location, Southern State university. X-2282-C.

ELECTRICAL ENGINEER, with several years' experience in design of D. C. machines, for manufacturer of electrical machinery. Apply by letter stating age, education, experience, references and salary expected. Location, Middlewest. X-2384-C.

RADIO ENGINEER, for research and development work in receiver circuits, for position with large stable radio corporation. Must have E. E. or equivalent degree and must have conducted original experimental investigations along similar lines. Apply only by letter. Location, New York City. X-2419.

DESIGNER, experienced on direct-current motors and generators of medium and large sizes. Must be native American and technically educated. Apply by letter. Location, Pa. X-2207-C.

ELECTRICAL ENGINEER, with five to seven years' experience since graduation, mostly on small motor design in industrial field, but with some teaching in courses on electrical engineering design. Also one who has had either the General Electric or Westinghouse Electric test course desirable. Location, Ohio. X-2475-C.

ELECTRICAL ENGINEER, thoroughly experienced in motor and motor-control design, preferably gained in elevator industry. Must be thoroughly familiar with slow-speed, alternating-current motors and controllers, and also with variable-voltage control. Records must show own successful designs on this type of equipment. Apply by letter. Location, Ohio. X-2255-C.

ELECTRICAL SALES ENGINEERS, who are thoroughly experienced with power transformers, or who have had experience selling similar lines to buying syndicates of public utilities. Apply by letter. Location East and Middlewest. X-1265-R-132-C.

MEN AVAILABLE

MECHANICAL AND ELECTRICAL ENGINEER, 33, graduated in Paris, ten years' experience in America as chief engineer, design, construction and operation, steam power plant, hydroelectric, transmission lines, substation, distribution systems, electric railroad, water work and cane sugar mills. Several languages. Desires position in Central or South America or West India. C-2727.

ENGINEER, young, desires position with consulting, contracting, or manufacturing concern. Trained chiefly in E. E., also some ability in civil and mechanical engineering. Two years' experience before graduation, two years' experience as graduate engineer with large public utility. Capable of executive position. Available at once. Location immaterial. C-2223.

EXECUTIVE ENGINEER, 32, married, mechanical engineer graduate, twelve' years diversified work industrial plants, large and small. Experience in design, manufacturing, construction and management. Now staff member of prominent consulting and management engineering corporation. Desires position in East not requiring traveling. C-43.

GRADUATE ELECTRICAL ENGINEER, desires to use his seven years' high-tension construction, testing and operation experience as a basis for sales engineering. Age 30, married. Middlewest preferred. B-6010.

INSTRUCTOR (part time), young electrical engineer, 30, married, graduate of E. E. Course at Cooper Union, ten years' experience in research laboratory of a large electrical concern, desires position as instructor of mathematics or sciences in the evening. Location, New York City. C-1780.

GRADUATE ELECTRICAL ENGINEER, 24, married, eighteen months G. E. test, desires position with engineering firm or public utility. Location immaterial. C-2737.

COMMERCIAL ENGINEER, graduate E. E. 1918, age 29, single, seven years' experience in public utility work on commercial, engineering and construction work. At present assistant divisional engineer, desires position as commercial engineer. Can furnish good references. Available on three weeks' notice. Salary $260 a month. C-2705.

CHIEF ELECTRICIAN, 32, married, taught school four terms, Army Air Service twenty-one months, commissioned twelve. One year factory electrical maintenance, three and one-half years hydro and steam electric central stations. Experienced in line, system operating and plant. Two and one-half years as erection and service man Allis Chalmers. At present employed as chief electrician in modern central station. Desires position as assistant to electrical executive who has plenty of work. C-2709.

MECHANICAL ENGINEER, Stevens 1922, having three years' independent experience as inventor and consultant on exploitation and patent problems, desires connection with an inventor, a promotor, or with a consulting firm engaged in adapting and marketing inventions. B-5758.

CONSTRUCTION OR OPERATING SUPERINTENDENT, electrical engineer graduate, thirteen years' experience in power plant construction, operating and maintenance of same, including substations, transmission lines and railway electrification. Age 36, married, Speaks Spanish fluently. Available May 15th. C-761.

ELECTRICAL ENGINEER, graduate high grade engineering college, age 44, married. Broad experience along mechanical and electrical lines covering large and small power apparatus, design and construction, experimental and research work. Technical teaching and organization. Particularly interested in power development and apparatus. B-129.

ENGINEER, skilled in design, manufacture and development; electrical, mechanical or chemical; graduate, American; diversified experience in

small and large machinery production. Can route machines through shops, reduce costs and establish profits to the manufacturer. Can lay-out and build the necessary additions to machine shops, plant, or power house. Financial experience. B-8863.

B. S. in E. E., who has had eighteen months General Electric test, seven months General Electric engineering office, and three years' teaching experience in the electrical engineering department of an accredited state engineering college as instructor and assistant professor teaching laboratory and theoretical subjects to both graduate and undergraduate students, desires a position for the summer. Age 25, single. Available in June. C-1669.

COLLEGE STUDENT IN ELECTRICAL ENGINEERING, 1928, age 30, desires work during summer months either in testing, in installation, or maintenance. Has had about two years of experience in power plant wiring and installation, and four years in general wiring and maintenance work. B-5279.

MECHANICAL AND ELECTRICAL ENGINEER, Cornell graduate, eighteen years' experience, including efficiency engineering for large industrial (paper mill) along steam and power production lines; combustion studies; boiler house rehabilitation work, etc. Industrial power engineering for utility. Prior to foregoing; supervision of electrical installations for large electrical manufacturer in an Eastern city. References. B-6764.

ELECTRICAL ENGINEER, college graduate, '26, age 28, single, speaks Russian, English and French, desires to work in company that deals with foreign countries. Location, any place. Available at any time. C-1981-10-C-3.

ELECTRICAL ENGINEER, with executive ability, competent in electrical and mechanical design and manufacture of electrical machines and apparatus; familiar with layout of transmission lines and substations; able to systematically carry on scientific and practical research work in electrical, mechanical and physical problems, with very good experience in automotive electric traction. Speaks German and French. Wishes to make new connection. C-693.

ELECTRICAL ENGINEER AND ENGINEERING EXECUTIVE, for consulting or construction organization. Reports, design, construction, contracts, office and field organization for industrial and utility power plants; acquainted with mechanical power equipment. Connection in Eastern Pennsylvania or New Jersey desired. C-2570.

POWER OR FACTORY ENGINEER, graduate, 27, married, two years of test course and other factory experience, one year with operating department, two years with station design department of a large hydraulic power company, desires position as assistant engineer with power company, or public utility, or in engineering or production department of manufacturing company. Eastern States. C-1524.

ELECTRICAL ENGINEER, 31, married, desires to change employment for climatic reasons. Has seven years of experience, and is competent in all phases of public utility and industrial engineering and administration. Should like to hear from public utilities, or engineering concerns, in the Metropolitan district. Available on one month's notice. C-658.

ENGINEER-ACCOUNTANT, graduated in electrical engineering; trained in a large operating company, experienced in supervision and management; ten years with a public service commission, mostly as departmental head; capable of taking charge of rate, valuation or accounting department, or managerial position; can prepare and present any utility case before a court or commission. C-2569.

TRANSMISSION LINE ENGINEER, university graduate, ten years' experience in design of transmission lines with special regard to mechanical features and safety. Experience includes formulation and application of safety codes, design of structures, standardization, sag and tension calculations, estimating, etc. At present in charge of transmission line design for large public utility. Location, East. C-2014.

DISTRIBUTION ENGINEER, technical graduate, five years' experience electrical and mechanical testing in power stations, five years' experience electrical distribution with large public utility. Desires position in distribution or sales engineering in distribution field. Available one month. B-1410.

ELECTRICAL ENGINEER, young, desires position with contracting or manufacturing concern. Has three years' experience in design, construction and operation of electrical transmission and distribution systems and equipment, also experience in central and substation design, construction and operation. Some experience in illuminating engineering. Has inventive ability. Speaks two foreign languages. Available immediately. Location preferred in United States. C-2223.

ELECTRICAL ENGINEER, 23, single, M. I. T. graduate 1925, two years' experience in test department of large power company. Desires position either on sales or technical staff with manufacturing company. Employed at present. Available on two weeks' notice. Location immaterial. C-1830.

TEACHER IN ELECTRICAL ENGINEERING, 27, married, S. B, and M. S. degrees, two years in engineering research, four years as instructor in Eastern university. Capable of taking charge of communication courses in university, or of commercial radio laboratory. Desires assistant professorship or position in industrial research. Available June 15th. C-2790.

GRADUATE ELECTRICAL ENGINEER, class 1926, at present taking student course with large utility company. Desires position with utility company in the South. Can leave on short notice. 29 years old, married. C-2788.

ELECTRICAL ENGINEER, 24, R. P. I. graduate in 1925, desires connection with a public utility or electrical contracting company. Two years' experience in maintenance and construction work. Location preferred, anywhere in United States. Available one month. C-2812.

SALES ENGINEER EXECUTIVE, with eighteen years' experience in specializing on oil breakers, insulators, lightning arresters and transmission specialties, desires a position in the Eastern section of the country. Wide acquaintance with central station field. C-2764.

CHARTERED ELECTRICAL ENGINEER, 29, resident in England, specialized in design, testing and operation of dynamos, motors, etc. Has held important appointments on design staff of Brush and Cromptons, and at present chief electrical designer to firm manufacturing mining machinery. Desires change to American firm. Would operate in Great Britain or abroad. Has car and office available. C-2787.

METER ENGINEER, 27, single, I. C. S. graduate E. E., nine years' experience, single and polyphase, primary and secondary meters. Short meter course with Westinghouse, also experience in conduit and open wiring. Foreman of meter department at present. Location preferred, anywhere in United States. Available thirty days. C-2831.

ELECTRICAL ENGINEER, technical graduate, eighteen years' experience development, design and manufacture of small electrical apparatus and instruments. Executive experience with both manufacturing labor and technical men. Thoroughly familiar with quantity production of quality apparatus and modern factory organization. American born, Christian. B-2721.

TEACHER IN ELECTRICAL ENGINEERING, 27, one and one-half years of teaching experience, university and high school. Holds B. S. and M. S. degrees from eastern technical school of highest standing. Desires position as teacher in electrical or related subject. New York City preferred. Available July 1927. C-211.

GRADUATE ELECTRICAL ENGINEER, B. S. in E. E., M. S. in Engineering Physics, one year as electrician and maintenance in large machine shop, two years as electrician in general repair shops, one and one-half years in electrical measurements laboratory. Desires position in development or application of electrical machinery. Just out of school. Married. Available about June 20th. C-2677.

ELECTRICAL ENGINEER, German university graduate, 31, married, with some experience in design of power plants and transmission lines and thorough practise in design, manufacturing and testing of electric motors. Since 1924 employed with the Westinghouse Company (designer of railway motors). Desires broader field of activity with railroad, public utility or manufacturing company. Location preferred, United States. C-2842.

ELECTRICAL ENGINEER AND COMMERCIAL ENGINEER, has two B. Sc. degrees, one in Electrical Engineering and the other Commercial Engineering from the University of Nebraska. Two years' experience in manufacture and testing of motors and transformers, and in sales office work. Experienced in tests and correspondence especially, and planning, as well as controlling operations. Would prefer construction work or maintenance work. C-2845.

ELECTRICAL ENGINEERING PROFESSOR, twelve years' teaching experience. Executive ability, accustomed to assuming responsibility. Married, 37. Desires position as professor in a technical school or university. Location preferred, Middlewest, Wisconsin or Southwest. C-2892.

INSTRUCTOR IN ELECTRICAL ENGINEERING, 30, single, five years' teaching experience and two years in industrial design and development work. Expert on d-c. and a-c. armature winding design. At present in charge of electrical department of large industrial school. Available July 1927. C-2893.

GRADUATE ELECTRICAL ENGINEER, 1925, desires position with a manufacturing or construction company. Eighteen months' experience low- and high-tension cable inspection. Location, New York. Available two weeks. C-512.

ELECTRICAL ENGINEER, 40, married, technical graduate with fifteen years' experience with public utility company in responsible position of operating supervision and substation electrical design. Desires position, preferably with holding company, where past experience would be of value and with future not limited to technical lines. Now engaged with operating company. Location preferred, Chicago. C-2894.

AGENTS REPRESENTATIVES

ENGINEER, well acquainted with important industrial and export buyers in New York Metropolitan District and environs and maintaining own sales office now distributing bituminous coal, is desirous of acquiring accounts from power equipment or supply manufacturers suitable for trade already developed. Highest class representation assured. B-6603.

AGENCIES desired for all Canada or Province of Quebec for electrical apparatus, instruments and accessory equipment, also associated mechanical equipment for mining, industrial and central station fields. Directing head of company has had long experience as sales manager and sales engineer, as well as sound designing and practical training. C-2498.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED APRIL 8, 1927

ACKERMANN, OTTO, Electrical Engineer, Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.

ADAMS, ARTHUR W., Station Superintendent, Utah Power & Light Co., Wheelon, Utah.

AHREND, FREDERICK A., Apprentice Engineer, Staten Island Edison Corp., Livingston, S. I., N. Y.

ALEXANDER, EDWARD BRITTAIN, Electrical Engineer, Lockport Light, Heat & Power Co., Lockport, N. Y.

ALTEMUS, FRANK B., System Operator, Counties Gas & Electric Co., Norristown, Pa.

ANDERSON, EDWARD K., Jr., Survey Tracer, Detail & Record Bureau, Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.

ANDERSON, FAYETTE CURTIS, Instructor in Electrical Engineering, Lehigh University, Bethlehem, Pa.

ANTLIFF, JAMES COOPER, Asst. to General Superintendent, Electrical Dept., Montreal Light, Heat & Power Co., Power Bldg., 83 Craig St., W., Montreal, P. Q., Can.

*ARNOTT, CLARENCE, Levelman, British Columbia Electric Railway Co., Ltd., 2050 Barclay St., Vancouver, B. C., Can.

*ASHLEY, RAYMOND L., Assistant to Electrical Engineer, Consolidated Gas, Electric Light & Power Co., Madison St. Bldg., Baltimore, Md.

AVELLA, SALVATORE RALPH, Distribution System Tester, United Electric Light & Power Co., 514 W. 147th St., New York, N. Y.

*BARBOR, VERNER HAROLD, Radio Engineering Assistant, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilmerding, Pa.

BARONIGIAN, BARONIG, Electrician, 235 W. 28th St., New York, N. Y.

BELIANINOV, NICOLAS, Chief Engineer, Design Dept., Factory "Electric"; Electrotechnical Institute, Leningrad, Russia.

BERRY, HARLEY SYLVESTER, Power House Operator, City of Los Angeles, Power Plant No. 2, Saugus, Calif.

BJORK, ATMORE F., Equipment Engineer, New York Telephone Co., 360 Bridge St., Brooklyn, N. Y.

BLEECKER, ANTHONY LISPENARD, Design Draftsman, Philadelphia Electric Co., 2301 Market St., Philadelphia; res., Ridley Park, Pa.

BOND, WILLIAM L., Jr., Supervisor, Wiring Bureau, Brooklyn Edison Co., 14 Rockwell Place, Brooklyn, N. Y.

BOVERI, THEODORE, Vice-President of Engineering, American Brown Boveri Electric Corporation, Camden, N. J.

BRADBURY, WILLIAM H., Chief, Kingston Coal Co., Market St., Kingston, Pa.

BRADFIELD, WILLIAM SIDNEY, Planning Engineer, Western Electric Co., 397 Hudson St., New York, N. Y.; res., Upper Montclair, N. J.

BROCK, MAURICE BAUM, Junior Engineer, Westchester Lighting Co., 22 S. 3rd Ave., Mt. Vernon; res., New York, N. Y.

*BROOKES, ALBERT SIDNEY, Cadet Engineer, Public Service Electric & Gas Co. of N. J., 80 Park Place, Newark, N. J.

BROWN, GEORGE HENRY, Field Engineer, Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.

BROWN, WILMER TOMLINSON, Assistant Electrical Designer, Philadelphia Electric Co., 10th & Chestnut Sts., Philadelphia, Pa.

BRYAN, WILLIAM J., Service Engineer, Victor Talking Machine Co., Camden, N. J.; res., Los Angeles, Calif.

BURKE, WILLIAM E., Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.

BURLINGHAM, KENNETH RALPH, Engineering & Supervising, Elect. Construction & Maintenance, Milwaukee County Institutions, Wauwatosa, Wis.

*CALDWELL, JAMES ALFRED, Assistant Engineer, Valuation Dept., Northern Indiana Public Service Co., Russel & Hohman Sts., Hammond, Ind.

CANNON, ROBERT SIMPSON, Draftsman, Electrical Engineer's Office, Pennsylvania Railroad, Altoona, Pa.

CHEATHAM, CADER WARREN, Commercial Surveys, Alabama Power Co., Birmingham, Ala.

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*CREVER, FREDERICK EMANUEL, Student Engineer, Testing Dept., General Electric Co., Schenectady, N. Y.

CUMMINS, WILLIAM M., Assistant Supt., Street Lighting Dept., Toledo Edison Co., Toledo, Ohio.

DALLY, THEODORE BEDFORD, Manufacturer's Agent, Mutual Electric & Machine Co. of Detroit, Mich., 30 Church St., New York, N. Y.; res., Maplewood, N. J.

*DALZELL, CLARENCE WILLIAM, Engineer, Engineering Dept., Union Switch & Signal Co., Swissvale; res., Wilkinsburg, Pa.

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DEAR, JOHN DAVID, Frame Inspector, Bell Telephone Co., 17th & Diamond Sts., Philadelphia, Pa.

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DeRYDER, HERBERT, Tester, New York Edison Co., 92 Vandam St., New York, N. Y.; res., Little Ferry, N. J.

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DOUGLAS, WILLIAM L., City Electrical Inspector, City Hall, Newark, N. J.

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MOHNS, CLARENCE EDWARD, Engineer, General Electric Co., Atlanta, Ga.

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*PECK, JONATHAN KENYON, Assistant Engineer, National Electric Light Association, 37 W. 39th St., New York, N. Y.

PELL, ERIC, Draftsman, The Milwaukee Electric Railway & Light Co., Public Service Bldg., Milwaukee, Wis.

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POTTER, JOHN EDWIN, Draftsman, General Electric Co., Pittsfield, Mass.

PRICE, MAURICE FRANKLIN, Chief Draftsman, Westinghouse Elec. & Mfg. Co., 30th & Walnut Sts., Philadelphia, Pa.

QUAIL, KENNETH H., Draughtsman, The Detroit Edison Co., 2000 Second Ave., Detroit; res., Royal Oak, Mich.

*QUINN, ROBERT PAUL, Cadet Engineer, United Gas Improvement Co.; for mail, Sioux City Gas & Electric Co., Sioux City, Iowa.

RALPH, CLIFTON McCAUSLAND, Electrical Draftsman, Electrical Engineering Dept., Union Oil Co. of California, Los Angeles; res., Long Beach, Calif.

RAYMOND, CHARLES D., Sales Engineer, General Electric Co., 20 Washington Place, Newark, N. J.

RIZZO, JERRY G., Electrical Contractor, 2284 First Ave., New York, N. Y.

ROCKEY, CARL HENRY, Supt. of Light & Water Dept., City of Alliance, City Hall, Alliance, Nebr.

RODGERS, LAURENCE AYLMER, Test Engineer, Canadian General Electric Co., Peterboro; res., Winnipeg, Man., Can.

*ROSE, CHESTER EUGENE, Instructor, Rensselaer Polytechnic Institute, Troy, N. Y.

RUOCCO, WILLIAM P., Jr., Electrical Expert, General Electric Co., 627 Greenwich St., New York; res., Brooklyn, N. Y.

SCHIMANSKY, BERNARD G., Engineering Dept., Toledo Edison Co., Jefferson & Superior Sts., Toledo, Ohio.

SCHLUP, ERNEST GODFRIED, Inspector, Engineering Dept., Brooklyn Edison Co., 561 Grand Ave., Brooklyn, N. Y.

SCHRAMM, FRANK GEORGE, Subway Engineer, Syracuse Lighting Co., 431 Fulton St., Syracuse, N. Y.

SEAGO, JOHN ALVIN, Transformer Engineering Dept., General Electric Co., 100 Woodlawn Ave., Pittsfield, Mass.

SELLIKEN, CONRAD FROSS, Foreman, Underground Service Crew, Northwestern Electric Co., Portland, Ore.

SHARER, FRANK SELDEN, Equipment Inspector, Rochester Telephone Corp., 820 Mercantile Bldg., Rochester, N. Y.

SHEPARD, GILBERT WATERMAN, Foreman, Repair Dept., Independent Wireless Telegraph Co., 67 Wall St., New York, N. Y.; res., Rutherford, N. J.

SHOGREN, EMIL, Electrician, Lord Electric Co., 112 Water St., Boston; res., Belmont, Mass.

SIMON, LUDWIG, Inspector, Brooklyn Edison Co. Inc., 561 Grand Ave., Brooklyn, N. Y.

SISSON, WILLIAM ALBERT, Electrical Superintendent, Niagara Ammonia Co., Inc., Niagara Falls, N. Y.

SMITH, B. HUNT BANCROFT, Sales Clerk, Central Station Div., Westinghouse Elec. & Mfg. Co., 150 Broadway, New York, N. Y.

SMITH, DONALD HARRY, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.

SMITH, MORRIS B., Chief Electrician, Sears Roebuck Co., 4640 Roosevelt Blvd., Philadelphia, Pa.

*SMITH, UEL LEE, Electrical Engineer, Supply Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

*SNOKE, DONALD LUTHER, Commercial Representative, Indianapolis Power & Light Co., 48 Monument Place, Indianapolis, Ind.

SNYDER, NORMAN, Electrical Engineer, General Engineering Laboratory, General Electric Co., Schenectady, N. Y.

SPENCER, WALTER HUTCHINS, Engineer, Montreal Light, Heat & Power Consolidated, Montreal; res., Westmount, P. Q., Can.

SPRY, PALMER, Electric Lines Inspector, Public Works Dept., Christchurch, N. Z.

*STAMATOV, GEORGE G., Test Engineer, General Electric Co., Schenectady, N. Y.

STARKE, RICHARD HENRY, Assistant Engineer, New York Telephone Co., 140 West St., New York, N. Y.; res., South Orange, N. J.

*STEEL, BEAUMONT A., Sales Engineer, Cutler-Hammer Mfg. Co., 323 N. Michigan Ave., Chicago, Ill.

STREULI, WERNER R., In charge of Electrical Testing, American Brown Boveri Electric Corporation, Camden, N. J.

STURZENEGGER, CHARLES ARNOLD, Electrical Engineer, Test Laboratory, American Brown Boveri Electric Corp., Camden; res., Collingswood, N. J.

SUMMERS, CLAY BELKNAP, Engineering Dept., Alabama Power Co., Birmingham, Ala.

SWANSON, RUDOLPH, Electrical Designer, Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

TAIT, WATSON FERGUS, Engineer, Public Service Electric & Gas Co., 80 Park Place, Newark, N. J.

TAYLOR, HAMILTON DANA, Electrical Designer, A. C. Engg. Dept., General Electric Co., Schenectady, N. Y.

TEMPLE, CECIL OLIVER, Distribution Agent, Snoqualmie District, Puget Sound Power & Light Co., Snoqualmie, Wash.

THICK, ROBERT WALTER, Chief Engineer, The Lahore Electric Supply Co., Ltd., McLeod Road, Lahore, Punjab, India.

THOMAS, CHARLES ALFRED, Electric Network Foreman, The Ohio Public Service Co., Alliance, Ohio.

THOMSON, CHARLES JOHN, Erecting Engineer, Contract Service Dept., General Electric Co., Schenectady, N. Y.

TROUTMAN, WILLIAM E., Squad Chief, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

VALENTINE, ALFRED S., Switchman, New York Telephone Co., 184th St. & Valentine Ave., New York, N. Y.

VAN ALSTYNE, D'ARCY, Equipment Engineer, New York Telephone Co., 360 Bridge St., Brooklyn, N. Y.

WAGONER, ARTHUR G., Foreman for Electrical Contractor, 1817 Pitken Ave., Brooklyn, N. Y.

WALL, JOHN VAN RENSSELAER, Engineering Dept., Stone & Webster, Inc., 147 Milk St., Boston; res., Winthrop, Mass.

WALLIN, CARL EINAR, Electrical Engineer, Wallin & Holmgren Electrical Works, 502 S. 13th St., Omaha, Nebr.

WALSH, JOHN GERSHOM, Testing Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

WALTER, CLARENCE F., Electrical Engineer, Cia. Cubana de Electricidad, Inc., Santiago, Cuba.

WARNER, RAYMOND ELLIOTT, Inspector, Electrical Engineering Dept., Brooklyn Edison Co., 561 Grand Ave., Brooklyn, N. Y.

WEINERTH, WESLEY, Assistant Supt. of Inspection, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.

WEITZENBERG, WILLIAM FREDERICK, Div. Supt. of Installation, Western Electric Co., Inc., 397 Hudson St., New York, N. Y.

WHITHED, HOUGHTON HAMILTON, Supt., Complaints & Adjustments, Puget Sound Power & Light Co., 7th & Olive, Seattle, Wash.

WIDMER, NICHOLAS, Electrical Engineer, American Brown Boveri Electric Corp., Camden, N. J.

WIGHT, WALTER CECIL, Substation Supt., Municipal Electricity Dept., Idgah, Simla, India.

WILLIAMS, ALBERT J., Jr., Design Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

WILLIAMS, LUTHER FRANKLIN, Assistant Engineer, Southern Pacific Co., Electrical Engineer's Office, S. P. Bldg., 65 Market St., San Francisco, Calif.

WILSON, STANLEY M., Supt. of Equipment, Western Electric Co., Inc., Kearny, N. J.

WILTSE, GEORGE ELMORE, Methods Engineer, Western Electric Co., Inc., 149 Fulton St., New York, N. Y.

WOOTEN, JAMES FREDERICK, Technical Inspector, Brooklyn Edison Co., Pearl & Willoughby Sts., Brooklyn, N. Y.

YOUNG, DAVID LAW, District Supt. of Installation, Western Electric Co., Inc., 397 Hudson St., New York, N. Y.

ZIEGLER, ARTHUR WILLIAM, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., South Orange, N. J.

Total 187.

*Formerly enrolled students.

ASSOCIATES REELECTED APRIL 8, 1927

BRESSLER, NORMAN JOHN, Operating Instructor, Metropolitan Edison Co., Reading, Pa.

GLEISS, FRANK J., Sales Engineer, Line Material Co., 1687 Atlantic St., Oakland, Calif.

GRIDLEY, SIDNEY D., Sales Engineer, The Okonite Co., 501 Fifth Ave., New York, N. Y.

PEASE, MAURICE HENRY, Vice-President & General Manager, Farmington River Power Co., Stanley Works, New Britain, Conn.

WEILL, STUART I., General Sales Engineer, Western Electric Co., Inc., 195 Broadway, New York, N. Y.

MEMBER REELECTED APRIL 8, 1927

ALLEN, NORVIN LOUIS, Supt., American Zinc Co. of Tennessee, Mascot, Tenn.

MEMBERS ELECTED APRIL 8, 1927

ALLISON, SEWELL WOODBERRY, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., West Orange, N. J.

BELLMAN, WILL E., General Inspector, The Western Union Telegraph Co., 195 Broadway, New York, N. Y.

BENDERNAGEL, WILLIAM H., Member, Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

BROOKS, BURTON HOTCHKISS, Vice-President & General Manager, Northern New York Telephone Corporation, 45 Oak St., Plattsburgh, N. Y.

CALLENDER, FRANK KER, Manager, Installation Dept., The Okonite-Callender Cable Co., 350 21st Ave., Paterson, N. J.

CHADBOURNE, DEAN K., General Manager, Westinghouse Electric International Co., 150 Broadway, New York, N. Y.; res., Plainfield, N. J.

CLARK, THOMAS C., Sales Engineer, W. N. Matthews Corporation, 3722 Forest Park Blvd., St. Louis, Mo.

COFFIN, PHILIP TRISTRAM, Electric Conductor Specialist, Aluminum Company of America, 120 Broadway, New York, N. Y.

HARRIS, JESSE, Chief Development Engineer, Duncan Electric Mfg. Co., Lafayette, Ind.

JEANNOT, FRED C., Electrical Engineer, The Bessemer Limestone & Cement Co., 714 Stambaugh Bldg., Youngstown, Ohio.

JORDAN, HENRY GRADY, Professor of Electrical Engineering; Head of the Dept., Colorado Agricultural College, Fort Collins, Colo.

KLINE, LOUIS MINES, Sr., Professor of Electrical Engineering, Linsly Institute, Theda Place, Wheeling; res., Elm Grove, W. Va.

OHNEMULLER, C. B., Supervisor, Brooklyn Edison Co., Inc., 380 Pearl St., Brooklyn, N. Y.

SCHUMACHER, WILLIAM ALFRED, Division Plant Engineer, Northwestern Bell Telephone Co., 709 Telephone Bldg., Omaha, Nebr.

SLEEMAN, HECTOR, Assistant Engineer, Rangoon Electric Tramway & Supply Co., 76 Merchant St., Rangoon, Burma, India.

STAHL, EDWARD C. M., Asst. Superintendent, Hudson Ave. Station, Brooklyn Edison Co., Brooklyn, N. Y.

WHEELER, EVAN RUPERT, Engineering Assistant, The Western Union Telegraph Co., 195 Broadway, New York, N. Y.; res., Plainfield, N. J.

TRANSFERRED TO GRADE OF FELLOW APRIL 8, 1927

ELMEN, GUSTAF W., Member of Technical Staff, Bell Telephone Laboratories, Inc., New York, N. Y.

HEIDENREICH, ALLAN H., Consulting Engineer, Cleveland, Ohio.

MILLAN, WALTER H., Supt. of Substations, Union Electric Light & Power Co., St. Louis, Mo.

SCLATER, I. H., Section Head, Transformer Engg. Dept., General Electric Co., Pittsfield, Mass.

TRANSFERRED TO GRADE OF MEMBER APRIL 8, 1927

ATKINSON, ALBERT A., Professor of Physics and Electrical Engineering, Ohio University, Athens, Ohio.

BATES, GEORGE M., District Manager, American Brown Boveri Elec. Corp., Boston, Mass.

BEALS, W. B., Outside Plant Engineer, Chesapeake & Potomac Telephone Co., Washington, D. C.

BILLHEIMER, C. R., Assistant to Vice-President, West Penn Power Co., Pittsburgh, Pa.

BLACKWEDEL, GEORGE H., Electrical Designer, 60 Wall Street, New York, N. Y.

BOLSTER, F. T., Electric Distribution Engineer, Syracuse Lighting Co., Inc., Syracuse, N. Y.

CHISHOLM, RAYMOND D., Sales Engineer, Westinghouse Elec. & Mfg. Co., New York, N. Y.

CLARKE, LIONEL C., Electrical Engineer, California Portland Cement Co., Colton, Calif.

COIT, NORMAN H., General Manager, Florida Public Service Co., Orlando, Florida.

COLE, HAROLD, Distribution Engineer, The Detroit Edison Co., Detroit, Michigan.

EBY, EUGENE D., Engineer, High Voltage Bushing Dept., General Electric Co., Pittsfield, Mass.

FAIRMAN, JAMES F., Assistant Electrical Engineer, Brooklyn Edison Co., Brooklyn, N. Y.

FISH, FREDERICK P., Lawyer, Fish, Richardson & Neave, Boston, Mass.

FORSTER, ROBERT, Engineer of Outside Plant, Up State, New York Telephone Co., Albany, N. Y.

FRY, AUGUST J., Assistant Engineer, Board of Supervising Engineers, Chicago Traction, Chicago, Ill.

GRANER, L. PETER, Electrical Engineer, Sprague Safety Control & Signal Corp., New York, N. Y.

HAZELTON, MERTON L., Assistant Electrical Engineer, Stone & Webster, Boston, Mass.

HOTCHKISS, FRED W., Sales Engineer, Electric Machinery Mfg. Co., Minneapolis, Minn.

JANSON, GEORGE W., Assistant to Apparatus Engineer, Western Union Telegraph Co., New York, N. Y.

KARUVEN, MULIYIL, Dy. Supt., Mills Division, Andhra Valley Power Supply Co., Ltd. & Tata Hydro Elec. P. S. Co., Bombay, India.

KOHL, GEORGE HUTTON, Hydraulic Engineer, Spanish River Pulp & Paper Mills, Ltd., Sault Ste. Marie, Ontario, Canada.

KREIDER, ROY H., Member of Technical Staff, Bell Telephone Laboratories, Inc., New York, N. Y.

LLOYD, WILLIAM E., Supt. of Transmission, Penna. Power & Light Co., Hazleton, Pa.

McPHAIL, HARVEY F., Engineer, U. S. Bureau of Reclamation, Denver, Colo.

MALADY, J. A., Mechanical and Electrical Engineer, Hillman Coal & Coke Co., Pittsburgh, Pa.

MICHELL, HUMPHREY G., Distribution Engineer, Cia. Mexicana de Luz y Fuerza Motriz, S. A. Mexico, D. F. Mexico.

MILLER, FRANK H., District Engineer, Public Service Co., West Chicago, Ill.

MORGAN, DON D., Supt. of Hydro Generation, Southern Calif. Edison Co., Los Angeles, Calif.

NULSEN, WILLIAM B., Radio Engg. Dept., General Electric Co., Schenectady, N. Y.

O'CONNELL, JAMES, Electrical Engineer, Virginia Public Service Co., Warrenton, Va.

PATES, ARTHUR J., Telephone Engineer, Chesapeake & Potomac Telephone Co., Washington, D. C.

PETERSON, ELMER G., Sales Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

RAMSEY, J. RAYMOND, Assistant to General Manager, Associated Gas & Electric Co., New York, N. Y.

SKINKER, MURRAY F., Assistant Director of Research, Brooklyn Edison Company, Brooklyn, N. Y.

STAVOLI, FRANCISCO J., Chief Engineer, Dept. of Radio and Electricity, Dept. of Education, Mexican Government, Mexico.

TAYLOR, DAVID B., General Supt. and Electrical Engineer, Troy Gas Company, Troy, N. Y.

THOMPSON, A. WARREN, Chief Engineer, Carolina Power & Light Co., Raleigh, N. C.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held April 5, 1927, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

HALL, HARRY Y., Supt., Hell Gate Station United Electric Light and Power Company, New York, N. Y.

To Grade of Member

LANG, RICHARD H., Chief Operator, Consolidated Gas, Electric Light and Power Company, Baltimore, Md.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1927.

Abbott, L. W., Victor X-Ray Co., Chicago, Ill.
Abrams, H. M., Cleveland Electric Illuminating Co., Cleveland, Ohio
Accarion, A., General Electric Co., Schenectady, N. Y.
Altfather, C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Andersen, F. N., Consumers Power Co., Saginaw, Mich.
Anderson, W. K., Commonwealth Edison Co., Chicago, Ill.
Andrews, C. A., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Andrews, J., Jr., Westinghouse Elec. & Mfg. Co., Detroit, Mich.
Ashton, R., American Brown Boveri Electric Corp., Camden, N. J.
Athanason, N. A., Commonwealth Power Corp., Jackson, Mich.
Augustinus, P., (Member), Marquette Elec. Switchboard Co., Chicago, Ill.
Autenrieth, H., Commonwealth Edison Co., Chicago, Ill.
Baker, H. W., Denton Engineering & Construction Co., Kansas City, Mo.
Barabas, J. J., Pennsylvania Railroad, Trenton, N. J.
Beal, J. A., Union Gas & Electric Co., Cincinnati, Ohio
Becherer, Max C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Beerbower, H. R., Consumers Power Co., Saginaw, Mich.
Bell, L. C., Illinois Power & Light Corp., Venice, Ill.
Bennett, A. F., Commonwealth Edison Co., Chicago, Ill.
Bonardel, L. F., Essex Power Station, Newark, N. J.
Boss, E. H., Kansas Electric Power Co., Lawrence, Kans.
Brannan, N. E., Efficiency Engineer, Proctor, Minn.
Briscoe, L. E., Bucyrus Shovel Co., So. Milwaukee, Wis.
Browne, P. J., Commonwealth Edison Co., Chicago, Ill.
Burke, E. F., Electrical Engineering & Mfg. Co., Cleveland, Ohio
Burke, T. F., (Member), Interborough Rapid Transit Co., New York, N. Y.
Burwell, J. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Cadwallader, W. C., Standard Underground Cable Co., Pittsburgh, Pa.
Caldwell, F. C., Ferranti Electric Ltd., Toronto, Ont., Can.
Campbell, J. E., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Carpenter, L. E., Commonwealth Edison Co., Chicago, Ill.
Casper, T. J., California Portland Cement Co., Colton, Calif.
Cassidy, A. R., Union Oil Co., Los Angeles, Calif.
Christiansen, H. P., Elevator Supplies Co., Hoboken, N. J.
Code, W. W., 1438 Madison St., Oakland, Calif.
Couy, C. J., Duquesne Light Co., Pittsburgh, Pa.
Darrin, L. T., Consulting Electrical Engineer, Philadelphia, Pa.
Davies, E. H., Commonwealth Edison Co., Chicago, Ill.
Davis, D. B., Counties Gas & Electric Co., Ardmore, Pa.
Davis, H. L., Jr., Philadelphia Electric Co., Philadelphia, Pa.
Davis, W. J., Commonwealth Edison Co., Chicago, Ill.
Deepe, R. M., Commonwealth Edison Co., Chicago, Ill.
Devin, W. C., Chester Valley Electric Co., Coatesville, Pa.
Dewitt, P. H., Illinois Power & Light Corp., St. Louis, Mo.
Dodds, H. E., Commonwealth Edison Co., Chicago, Ill.
Dodds, R. B., Yale University, New Haven, Conn.
Dow, C. O., Electrical Controller & Mfg. Co., Cleveland, Ohio
Dowell, J. C., General Electric Co., Schenectady, N. Y.
Duer, C., Western Union Telegraph Co., Omaha, Nebr.
Duignan, H. E., Metropolitan Edison Co., Reading, Pa.
Dumke, W. C., Commonwealth Edison Co., Chicago, Ill.
Elgin, E. K., Commonwealth Edison Co., Chicago, Ill.
Ellison, M. J., Canadian & General Finance Co., Toronto, Ont., Can.
Ellmore, W. A., Scanlon Electric Mfg. Co., Chicago, Ill.
Fairbanks, S. J., Waterloo, Cedar Falls & No. Railway, Waterloo, Iowa
Fay, C. E., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Fife, J. L., Commonwealth Edison Co., Chicago, Ill.
Fischer, G. H., Commonwealth Edison Co., Chicago, Ill.
Fischer, R. M. O., Bucyrus Co., So. Milwaukee, Wis.
Fitzsimmons, L. G., Pacific Tel. & Tel. Co., San Francisco, Calif.
Fowler, F. R., Southern California Edison Co., Big Creek, Calif.
Fowler, W. J., Power Plant Dept., City of Jacksonville, Jacksonville, Fla.
Franklin, H. D., Bucyrus Co., So. Milwaukee, Wis.
Frick, D. H., Western Electric Co., Detroit, Mich.
Gabree, J. V., Western Electric Co., Inc., Chicago, Ill.
Galphin, C. B., with J. E. Sirrine & Co., Greenville, S. C.
Garrett, P. A., Commonwealth Edison Co., Chicago, Ill.
Gell, C. F., Commonwealth Edison Co., Chicago, Ill.
Gerdanc, F. G., Commonwealth Edison Co., Chicago, Ill.
Gross, C. M., Commonwealth Edison Co., Chicago, Ill.
Guillou, A. V., (Member), California Railroad Commission, San Francisco, Calif.
Gustafson, H. G. H., Commonwealth Edison Co., Chicago, Ill.
Halvorsen, C. L. S., Otis Elevator Co., Yonkers, N. Y.
Hancock, E. W., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Harmony, C. A., Puget Sound Power & Light Co., Bothwell, Wash.
(Applicant for re-election.)
Harrington, F. C., Commonwealth Edison Co., Chicago, Ill.
Harris, S. G., Jr., Page & Hill Co., Minneapolis, Minn.
Haskell, E. B., General Electric Co., Schenectady, N. Y.
Helt, O. B., Helt & O'Donnell, Portland, Ore.
(Applicant for re-election.)
Henny, I. B., Edison Electric Co., Lancaster, Pa.
Hildebrandt, T. F., New York Telephone Co., Brooklyn, N. Y.
Hill, G. H., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Holloway, C. F., Commonwealth Edison Co., Chicago, Ill.
Hopkins, I. B., Philadelphia Electric Co., Philadelphia, Pa.
Hudson, H. L., American Agricultural Chemical Co., Pierce, Polk Co., Fla.
Hughson, C. O., Southern Bell Tel. & Tel. Co., Dunnellon, Fla.
Hummel, L. R., Duquesne Light Co., Pittsburgh, Pa.
Humphrey, H. C., Vitaphone Corp., New York, N. Y.
Hyde, M. A., Jr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Jaboolian, E., Gibbs & Hill, Inc., New York, N. Y.
Jackson, W. C., 336 15th Ave., San Francisco, Calif.

Jaegle, W. H., Louisville Gas & Electric Co., Louisville, Ky.
Jansson, E. O., Holtzer-Cabot Electric Co., Roxbury, Mass.
John, S. W., Scofield Engineering Co., Philadelphia, Pa.
Johnson, C. L., General Electric Co., Pittsfield, Mass.
Johnson, J. L., Capital Traction Co., Washington, D. C.
Jones, B. D., Jr., Commonwealth Edison Co., Chicago, Ill.
Jones, H. C., (Member), Byllesby Engg. & Management Corp., Birmingham, Ala.
Kellogg, W. M., University of Arizona, Tucson, Ariz.
Kenny, J. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Keys, P. R., Commonwealth Edison Co., Chicago, Ill.
Kilkenny, J. E., Inman Poulsen Lumber Co., Portland, Ore.
Kinney, E. E., Michigan State College, East Lansing, Mich.
Kinney, L. K., Commonwealth Edison Co., Chicago, Ill.
Kolodziej, P. J., Public Service Electric Corp., Elizabeth, N. J.
Kradel, F. L., West Penn Power Co., Pittsburgh, Pa.
Kramer, L. W., Teacher, Board of Education, Philadelphia, Pa.
Kraus, R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Kubik, E. C., Union Electric Co., St. Louis, Mo.
Kuckes, H. F., New York Central Railroad, New York, N. Y.
Laffsa, A. E., (Member), with Barker & Wheeler, New York, N. Y.
Lamb, M. D., Commonwealth Edison Co., Chicago, Ill.
Larson, C. J., Commonwealth Edison Co., Chicago, Ill.
Larson, F. A., Bucyrus Co., So. Milwaukee, Wis.
Lathrop, F., Southeastern Underwriters Association, Atlanta, Ga.
Leeming, H. H., (Member), Hydro-Electric Power Comm., Toronto 2, Ont., Can.
LeVan, W. A., New York State Railways, Rochester, N. Y.
Levy, A., Commonwealth Edison Co., Chicago, Ill.
Lynch, E. D., Westinghouse Elec. & Mfg. Co., New Haven, Conn.
Lynes, F. C., Arizona Edison Co., Yuma, Ariz.
Mackay, R. W. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Mag, A., Duquesne Light Co., Pittsburgh, Pa.
Maresh, E. J., Commonwealth Edison Co., Chicago, Ill.
Martin, G., (Member), Snook-Hillhouse & Co., Columbus, Ohio
Matzner, T. C., Commonwealth Edison Co., Chicago, Ill.
Mayo, C. R., Commonwealth Edison Co., Chicago, Ill.
Mazanec, W., Union Electric Light & Power Co., St. Louis, Mo.
McElroy, C. E., Commonwealth Edison Co., Chicago, Ill.
McGinnis, A., San Pedro High School, San Pedro, Calif.
McGuire, W. H., Retsof Mining Co., Retsof, N. Y.
McKinley, V. L., Louisville Gas & Electric Co., Louisville, Ky.
McLoughlin, J., Philadelphia Electric Co., Philadelphia, Pa.
Melton, B. S., Gulf States Utilities Co., Port Arthur, Texas
Menzies, J. A. B., American Brown Boveri Corp., Camden, N. J.
Merrill, S. O., Commonwealth Edison Co., Chicago, Ill.
Merryman, J. A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Milne, F. J., Hydro-Electric Power Commission, Toronto, Ont., Can.
Moore, V., Commission of Public Docks, Portland, Ore.
Murray, C. M., Jr., University of Washington, Seattle, Wash.
Mustoe, A. Q., Duquesne Light Co., Pittsburgh, Pa.
Neill, J. K., Portland Electric Power Co., Portland, Ore.
(Application for re-election.)
Noll, W. H., Commonwealth Edison Co., Chicago, Ill.
O'Donnell, J. J., Helt & O'Donnell, Portland, Ore.
Olesen, H. L., (Member), Fansteel Products Co. Inc., North Chicago, Ill.
Olmedo, J. H., National Telegraph, Mexico City, Mex.
Olson, L. W., Duquesne Light Co., Pittsburgh, Pa.
Parsons, W. S., Apex Rotorex Corp., New York, N. Y.
Peck, V. S., Commonwealth Edison Co., Chicago, Ill.
Perrone, S. J., U. S. Government, Ellis Island, New York, N. Y.
Petersen, Melvin L., Commonwealth Edison Co., Chicago, Ill.
Phillips, F. R., (Member), Duquesne Light Co., Pittsburgh, Pa.
Rebmann, W., Franklin Porcelain Co., Norristown, Pa.
Reed, R., Florida Power & Light Co., Fort Myers, Fla.
Renick, R. D., Illinois Power & Light Corp., St. Louis, Mo.
Rice, I. S., Commonwealth Edison Co., Chicago, Ill.
Richter, C. W., Atlantic Refining Co., Philadelphia, Pa.
Riggs, L. H., Commonwealth Edison Co., Chicago, Ill.
Ritner, F. C., West Penn Power Co., Pittsburgh, Pa.
Robertson, A. W., Philadelphia Co. & Affiliated Corp., Pittsburgh, Pa.
Robinson, H. G., Pacific Tel. & Tel. Co. Seattle, Wash.
Rubenstein, M., Standard Underground Cable Co., Philadelphia, Pa.
Runge, A., Public Service Electric & Gas Co., Jersey City, N. J.
Ryan, J. L., New York Central Railroad Co., New York, N. Y.
Sands, W. F., Atwater Kent Mfg. Co., Philadelphia, Pa.
Scales, G. B., New England Structural Co., Everett, Mass.
Scharff, M. R., Byllesby Engg. & Management Corp., Pittsburgh, Pa.
Schauer, F. F., Duquesne Light Co., Pittsburgh, Pa.
Schmertz, P., Honolulu Iron Works Co., New York, N. Y.
Schmidt, W. H., General Electric Co., Schenectady, N. Y.
Schomacker, W. W., Commonwealth Edison Co., Chicago, Ill.
Schuchert, J. S., Duquesne Light Co., Pittsburgh, Pa.
Seeley, H. T., General Electric Co., Philadelphia, Pa.
Shirkey, C. O., Commonwealth Edison Co., Chicago, Ill.
Shirosaki, K., Toho Electric Power Co., Tokio, Japan. (For mail, Wilkinsburg, Pa.)
Smith, D. L., (Member), Chicago Rapid Transit Co., Chicago, Ill.
Smith, M. E., Commonwealth Power Corp., Jackson, Mich.
Smith, R. J., Department of City Transit, Philadelphia, Pa.
Smith, W. A., Commonwealth Edison Co., Chicago, Ill.
Sparks, L. D., Commonwealth Edison Co., Chicago, Ill.
Squires, H. G., (Member), Illinois Power & Light Corp., St. Louis, Mo.
Stahl, W. A., Missouri Pacific Railroad, St. Louis, Mo.
Stapley, M. L., Commonwealth Edison Co., Chicago, Ill.
Stempfle, F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Stevens, E. E., Commonwealth Edison Co., Chicago, Ill.
(Applicant for re-election.)
Stigers, G. H. W., Commonwealth Edison Co., Chicago, Ill.
Stilwell, W. H., Louisville, & Nashville Railroad Co., Louisville, Ky.
Stolte, H. J., New York Telephone Co., Brooklyn, N. Y.
Strauss, A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Temple, C. D., General Electric Co., Schenectady, N. Y.
Thies, F. A., Brooklyn Edison Co., Brooklyn, N. Y.
Thompson, W. S., N. Y. & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
Thomson, P. L., Commonwealth Edison Co., Chicago, Ill.
Toburen, J. O., Air Core Technical School, Rantoul, Ill.
Tupper, F. M., Moloney Electric Co., Philadelphia, Pa.
Turner, F. R., c/o J. Barnes, 30 Fifth Ave., New York, N. Y.
Tweddell, A. E., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Twyman, C. F., Louisville Gas & Electric Co., Louisville, Ky.
Van Horn, J. C., (Member), Philadelphia School of Wireless Telegraphy, Philadelphia, Pa.
Wagner, E. H., Commonwealth Edison Co., Chicago, Ill.
Walker, G. A., Commonwealth Edison Co., Chicago, Ill.
Walther, A., Pacific Gas & Electric Co., Modesto, Calif.
Wardlow, H., Philadelphia Electric Co., Philadelphia, Pa.
Weir, P. L., Byllesby Engineering & Management Corp., Pittsburgh, Pa.
Werner, A. F., Packard Electric Co., New York, N. Y.
Weston, W. H., Commonwealth Edison Co., Chicago, Ill.
Wilcox, H. M., (Member), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Wild, E., Commonwealth Edison Co., Chicago, Ill.
Wilson, H. A., Canadian Niagara Power Co., Ltd., Niagara Falls, Ont., Can.
Winchester, L. S., (Member), Duquesne Light Co., Pittsburgh, Pa.
Wing, L. S., California Farm Bureau Federation, San Francisco, Calif.
Winter, P. H., Scranton Electric Co., Scranton, Pa.
Witty, B. G., General Electric Co., Schenectady, N. Y.
Wohlauf, R. H., 606 W. 137th St., New York, N. Y.
Wood, H. A., Commonwealth Edison Co., Chicago, Ill.
Woolley, S. L., Byllesby Engineering & Management Corp., Pittsburgh, Pa.
Wright, A. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Youle, B. J., Brooklyn, N. Y.
Zepp, R., Commonwealth Edison Co., Chicago, Ill.
Zondervan, B., Western Electric Co., Chicago, Ill.
Total 219.

Foreign

Attwood, F., (Member), Ohio Brass Co., Mansfield, Ohio; (Res. Paris, France.)
Bhupathy, K. K. A., Government Trades School, Madras, India
Bruce, J. M., Queensland Irrigation Commission, Brisbane, Queensland, Aust.
Deem, J. S. L., (Member), Borough Electrical Engineer, Raetihi, N. Z.

Evans, R. L., Municipal Electricity Department, Shanghai, China
Gilbert, S. W. T., Engineering Journalist, Secunderabad, Deccan, India
Hikino, S., Hanshin Kyuto Dentetsu, Osaka, Japan
Mashkilleyson, L., Electrotechnical Institute, Leningrad, Russia
McCaleb, T. S., Liberian Government, Monrovia, Liberia, West Africa
Skaar, E., Skandinavisk, Kabel & Gummifabriker, Nordal, Aker, Norway
Srinivasan, M. T., (Member), Elec. Engineer, T. T., etc., Devasyanams, Tirupati, S., India
Total 11.

STUDENTS ENROLLED

Acuna, Louis F., Engineering School of Milwaukee
Adams, Joseph E., Harvard University
Andrews, Ransom H., Duke University
Appelquist, Fred V., State College of Washington
Asimow, Morris, University of California
Banos, Alfredo, Jr., Johns Hopkins University
Barnes, Jarvis B., North Carolina State College
Barrier, John J., North Carolina State College
Beck, George R., Engg. School of Milwaukee
Benzinger, A. E., University of California
Bertucci, John F., University of California
Bowman, Lyle H., University of California
Braid, Edward H. B., West Virginia University
Branch, Daniel B., Jr., North Carolina State College
Brown, James F., University of California
Brown, Stanley L., University of California
Browne, Thomas E., Jr., North Carolina State College
Bryan, Herbert H., University of Toronto
Bryant, Mariner W., State College of Washington
Burns, Robert E., University of Wyoming
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Total 95			

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NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Transformers.—Bulletin 148, 32 pp. Describes Wagner single-phase distribution transformers. Wagner Electric Corporation, St. Louis, Mo.

Insulators.—Bulletin, describes "Pyrex" power line insulators for operating voltages from 6600 to 50,000 volts. Corning Glass Works, Corning, N. Y.

Transformers.—Bulletin GEA 314, 36 pp. Describes General Electric street lighting transformers. General Electric Company, Schenectady, N. Y.

Traffic Signals.—Bulletin GEA-566, 26 pp. Describes "Novalux" traffic signals and systems of control for traffic movement. General Electric Company, Schenectady, N. Y.

Insulators.—Catalog, 36 pp. Describes a complete line of glass insulators for telephone, telegraph and medium voltage power lines. Production processes are also pictured. Hemingray Glass Company, Muncie, Ind.

Steam Turbine Lubrication.—A recent issue of "Lubrication," published by the Texas Company, 17 Battery Place, New York, contains a comprehensive treatment of the subject of steam turbine lubrication.

Motors.—Bulletin 200, 32 pp. Describes type "T" heavy duty Reliance motors for direct current. The bulletin is profusely illustrated. The Reliance Electric & Engineering Co., Ivanhoe Road, Cleveland, Ohio.

Lighting for Street Traffic Control.—Bulletin LD 147A, 28 pp. Describes systems and apparatus used in lighting for street traffic control. Edison Lamp Works of General Electric Company, Harrison, N. J.

Motor Maintenance Equipment.—Catalog 8, 32 pp. Describes commutator grinding tools, armature repairing tools, slotting and grinding outfits, undercutters, commutator slotters, insulation and voltage testing instruments, portable blowers, cable fittings, conduit hangers, etc. The bulletin also contains a carbon brush maintenance and trouble chart. The Martindale Electric Company, 1260 West 4th Street, Cleveland, Ohio.

Illumination Terms.—Bulletin LD 155, 56 pp., is a comprehensive directory of terms used in connection with illumination. The definitions presented in the American Engineering Standards Committee Report on "Illuminating Engineering Nomenclature and Photometric Standards" have been followed in all cases in which they apply, and in addition explanatory or illustrative material has been included. Edison Lamp Works of General Electric Company, Harrison, N. J.

NOTES OF THE INDUSTRY

The Brown Instrument Company, Philadelphia, has opened a branch office at Cincinnati, Ohio, in the First National Bank Building. Mr. J. R. Green is district manager.

The Baitinger Electric Company, Inc., New York representatives of the Trico Fuse Manufacturing Company, have moved to 95 Chambers Street, New York.

General Electric Earnings for First Quarter of 1927.—Orders received by the General Electric Company for the three months ending March 31, 1927, totalled $77,550,581, compared with $86,433,658 for the same quarter in 1926, a decrease of 10 per cent.

The Ohio Brass Company, Mansfield, Ohio, has appointed David H. Moore, formerly assistant to the secretary of the company as district sales manager, with headquarters at 50 Church Street, New York. He will operate in parts of New York, New Jersey, Pennsylvania and the New England states. Mr. Moore spent seven years with Day & Zimmermann, Inc., Philadelphia in consulting and general engineering work before going to the Ohio Brass Company.

A 1,000,000 Kw. Generating Station.—The New York Edison Company has published a 32-page bulletin describing the new East River generating station. Accommodation has been provided in the main structure for nine steam turbines; the first two, already installed, have a capacity of 60,000 kw. each. The ultimate capacity of the station is over one million kilowatts.

The Burndy Engineering Co., Inc., 10 East 43d Street, New York, announce that they are now ready to supply Anaconda copper tubing, also flat and round bars, with Burndy connectors.

A copper silicon-manganese alloy, made by the Anaconda Copper Mining Company, is now standard for all bolts and U-bolts in Burndy connectors at no increase in price. According to laboratory tests and field use, this metal, known as "Everdur," was found most resistant to mechanical strain and corrosion.

New Rail Motor Cars for Rock Island Lines. The Rock Island Lines, which is placing seven new gas-electric cars in operation, is the first railroad to substitute motorized power for both passenger and light freight service on branch lines. Before being placed in regular service, the fleet was exhibited during April in St. Louis, Kansas City, Des Moines and Chicago.

The cars are of a new type which burn as fuel a petroleum distillate such as is used in residence oil furnaces. According to E. Wanamaker, electrical engineer of the Rock Island Railroad, the cars will solve the biggest problem now confronting the railroads of the middle west, that of economic and successful handling of traffic on branch lines, which he declares is no longer possible with steam locomotives. These cars are capable of hauling a passenger train of 200 tons train weight at the speed of regular steam trains, and at a cost of less than half what steam trains cost today. All of the electric equipment was built by the General Electric Company.

Russian Power Developments.—The Amtorg Trading Corporation, New York, announce the following recent power plant developments in the Soviet Union:

Construction will soon begin on a new hydroelectric plant on the Kamenka river in Soviet Armenia, to cost $4,000,000. An order has been placed with the Metallichesky Works in Leningrad for the construction of a 20,000 kw. turbine and other equipment for the station.

A new power plant of 1800 kw. to cost $1,000,000 is under construction in the town of Pskov.

A new electric power plant of 1300 kw. has been opened in the coal fields of the Kuznetz basin.

A new electric power plant, capacity 6000 kw. at Sverdlovsk, in the Urals, operating on peat fuel, was opened March 12.

Construction of a new electric power plant, 44,000 kw. began at Cheliabinsk, Siberia, during April, to supply current for large metallurgical works and mines in the district.

During the summer construction will begin on a large electric power plant operating on peat fuel at Ivanovo-Vosnesensk. Initial capacity will be 44,000 kw., final capacity 88,000 kw.

A new power plant of 22,000 kw. will be placed under construction shortly at the Black Sea port of Novorossisk. It will supply power to local cement plants, grain elevators, etc.

A new power plant, 21,000 kw. to supply power to the Grozny oil fields and contiguous regions, will be built on the Gizel-Don river in the Northern Caucasus.

Construction of a hydroelectric plant, 6000 h. p., has been begun on the Vyg River in Northern Karelia. Large deposits of copper, iron and other metals have been charted in this section.

A 30,000 kw. steam turbine, the largest in the Soviet Union was installed in the First Leningrad Power Plant in March.